W. L. Miggett,
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Boiler Construction

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A PRACTICAL EXPLANATION OF THE BEST MODERN METHODS OF BOILER CONSTRUCTION FROM THE LAYING OUT OF SHEETS TO THE COMPLETED BOILER

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Preface.

In presenting this work it is not intended to give a large quantity of theoretical matter which would be uninteresting to the builder; nor to give a lot of new, untried material. The matter which has been compiled for this work represents the most modern practice. Only the best and the most rapid methods of the large builders and railroads are given, so that one following the line of work which is here laid out will not run behind in these modern days of progress.

In trying to get this matter together in such shape as to be generally useful, it has been deemed inadvisable to illustrate and describe the methods used by the builders of each one of the many prominent boilers now being built for various classes of work. And as the different operations on different makes of boilers are so similar to each other, it has been considered best to devote a section to the description of boilers in general. Following this, the locomotive boiler is taken up in the order in which the matter goes through the shop.

It begins with the laying out of sheets, and gives the necessary information that will enable a boiler maker to lay out the different sheets which go together to make up the boiler. Several methods have been given for the development of the slope sheet, as it is not always possible to lay out this sheet by the same methods. Then follows a section on shearing. At this time all the superflous metal is removed and the sheet is prepared for the flanging operation. After the sheet is flanged, the superflous metal must be trimmed off, the holes punched or drilled as the case may be and the edges prepared for calking.

A section is then devoted to bending, as there is scarcely a boiler of any size or style which does not have to go through the bending roll sometime during its construction. Then follows a section on assembling and calking, and one on details.

Owing to the misuse that the machines in the boiler shop receive, it has been considered best to add a section on boiler shop machinery, showing the points of the machine which are liable to become broken through carelessness; and also such other instructions which would enable one to keep his machine in good running order and make any repairs which are necessary from time to time.

Sections are given on the testing of the boiler and finally one is devoted to useful tables. These tables have been grouped together and are intended to give one, as near as possible, all the matter which is necessary in connection with the construction of a boiler, together with the stresses which would be set up in the various members due to the steam pressure and expansion.

A short description of tables has been given wherever it has been considered necessary. Following this will be found a number of plates showing several different types of modern locomotive boilers. In the selection of the sheets as examples and also in the plates, etc., the most difficult sheets have been selected and a different variety of boilers chosen, so that a person becoming capable of laying out and following these sheets through the shop would have no difficulty in handling any boiler made.

Various Types of Boilers.

Generally speaking there are many types of boilers being made to suit the various conditions of space, locality, water, fuel, etc. In all of them, however, we have one or the other or both of two underlying principles in their construction. First, the form in which heat is applied from the inside of the tubes, usually known as the fire tube boiler. Second, the form in which heat is applied outside of the tube, which is generally known as the water tube boiler. A good example of the water tube boiler will be found in the Babcock & Wilcox boiler. The tubes in this boiler are inclosed at an angle to the horizon and they are divided lengthwise into sections so that the gases coming from the furnace pass through one of the sections, are deflected down through another, then turn vertically and pass through the third section from which they are led off into the chimney.

The ends of these tubes are secured in steel headers and over each tube or nest of tubes we have a cover plate. The steam as it is generated in these tubes must be conducted to a dome of some sort in order that we may have a store of steam on hand. This usually takes the form of a cylindrical drum which is rolled up and riveted in the same manner as the locomotive or vertical boiler. The heads are made of flanged steel and are usually provided with hand holes for cleaning. Of course this boiler is only taken as an example of many other boilers of similar construction and which differ from this boiler in the location and arrangement of the various parts.

The Heine boiler is another example. These are made in very large units, each of which occupies considerable space. The tubes are inclined at an angle and are secured at each end to heads which are made of flanged steel. The head is composed of two pieces; each one of these pieces is riveted to a tie piece, thus forming a box of great strength. These two boxes are flanged out at the top to receive a cylindrical shell which not only serves as a storage space for steam but is also partly filled with water.

This shell is made up in exactly the same manner as the various courses of a locomotive boiler. The two examples which have been given represent good modern construction of water tube boilers and while there are many different makes of water tube boilers, yet there are thousands of places where the fire tube boiler is preferred for one reason or another and so we find as many different types of fire tube boilers in operation in all parts of the country and for all classes of work. In the case of the Scotch marine boiler the grate is entirely enclosed within the boiler itself. The gases impinge against the walls of the fire box and then pass through the inside of a large number of tubes. The gases then turn and come back through another series of tubes to the front end of the boiler, passing from here into the stack. In this type of boiler we have a cylindrical shell which is built up of riveted plates. The ends of the boiler are provided with flanged heads into which the tubes are secured.

The fire box has many different forms, but they are classed under the head of one, two, or three-furnace, as the case may be. There are also many boilers used for marine purposes which are very similar to the locomotive boiler, being arranged with a fire box, combustion chamber and the usual arrangement of tubes as seen on the general run of locomotive boilers. They are rarely used as a single boiler, but are arranged in a bank of two or more and fitted up with steam connections and steam drums so that any one of the boilers can be taken out of service without interfering with the rest.

Then we have, both upon land and water, a type of boiler which, owing to its simplicity, is so largely found everywhere we go. It consists of a cylindrical tube of large diameter built up in a similar manner to the various courses of a locomotive boiler and arranged with two cylindrical flanged heads. Into these heads are secured tubes of large diameter. The furnace is supported upon braces which are riveted to the side and which are built into brick walls. The hot gases coming from the fire play against the bottom of this horizontal boiler, pass to a combustion chamber at the far end, then turn and come back through the tubes and finally off to the chimney or stack.

The machinery for handling the different operations on these boilers is exactly the same as that used in a locomotive boiler shop, but, of course, the operations are much more simple. The dies are easily constructed and things can be kept more to a standard than in any other class of boiler.

We then have a class of boilers which are largely used in different forms which, instead of being located in a horizontal position, is vertical. Many of the boilers of small capacity for both stationary or portable work are designed in this manner. The fire box is enclosed within the boiler. From the upper portion of the fire box fire tubes lead to the top of the boiler and are secured to a flanged head. The boiler is cylindrical and the sides extend on through to receive the connections for the stack. Of course this is a cheap boiler to build. The process of laying out the different parts is comparatively simple but with these advantages of construction there comes along with the boiler a disadvantage and that is that it is not at all economical in the consumption of fuel necessary to run it.

We thus find that whatever style of boiler we take up it has much in common with the locomotive boiler. In addition to these two classes of boilers there is still another class which is a combination of both the water tube and fire tube, thus the lower portion of a certain make is arranged with water tubes while the top portion is arranged with fire tubes. Of course these tubes may be large or small, indeed the range is so great that with the increased size of the tubes, it is either necessary to corrugate the tubes as in the case of those in which the fire box is enclosed within the boiler as in many types of marine boilers. Or else the tube must be stayed externally to keep it from collapsing. In the Galloway boiler, for instance, we have a tube which is not cylindrical but which is prevented from collapsing by conical cross tubes which are flanged out on the ends and riveted to the side of the boiler.

The various fire boxes, combustion chambers, steam drums, domes, fittings, etc., have in them much the same idea as we find in the locomotive boiler. As the locomotive boiler better represents the general class of boilers than any other and as this class of boilers is so extensively used at the present day and must necessarily be used for many years to come, it has been deemed advisable to use it as an example of steam boilers and treat the various operations of laying out, shearing, flanging, bending, riveting, etc., under their separate heads. Anyone who is capable of taking the complicated flanged sheets of some of our modern locomotive boilers and follow them through from the laying out bench to the hydraulic press, to the riveting machine and finally to the finished boiler, would be capable of handling any of the sheets found in the construction of any other style of boiler.

The various details given under the head of boiler details of course applies to the locomotive boiler, but the arrangement of the safety valves, check valves, injectors, domes, etc., bear a striking similarity to each other on whatever type of boiler we may choose to take up.

Gusset sheet development.

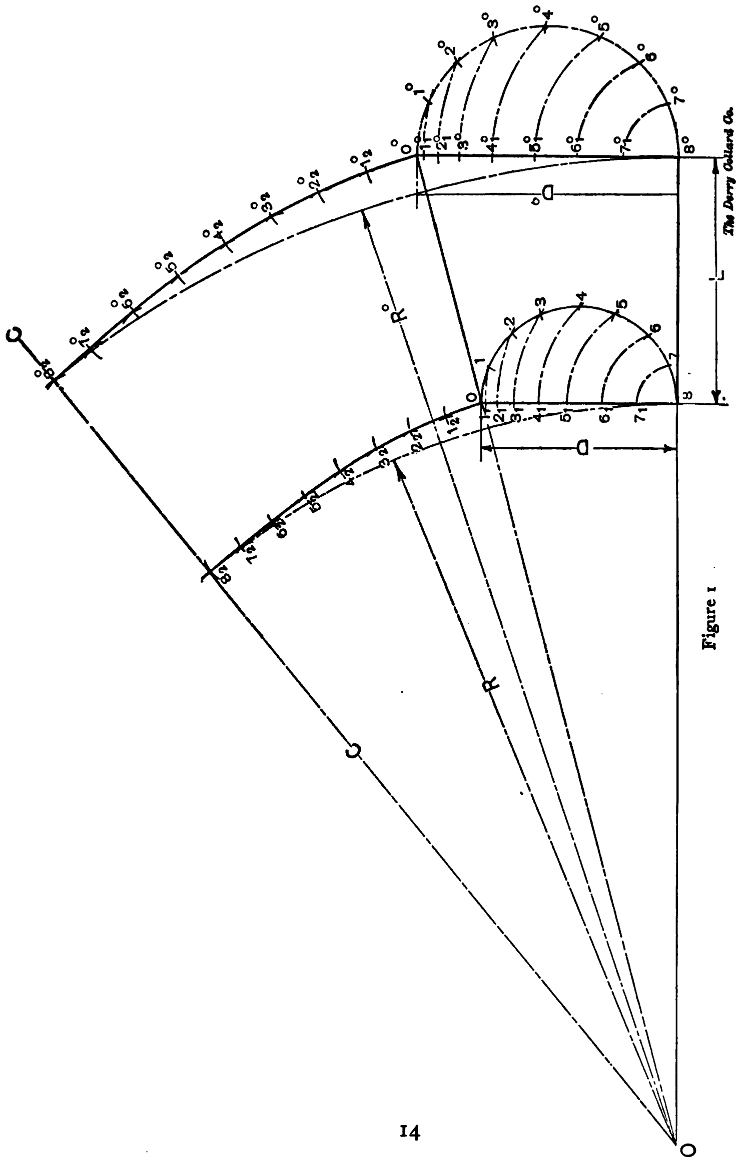


Figure 1
Development of a gusset sheet.

The Practical Construction of the Locomotive Boiler.

Laying Out Work.

In the general make up of the Locomotive Boiler, there are many cylindrical sheets, and in addition to these, there are others, such as the gusset or slope sheet, crown sheet, side sheets, throat sheet, etc., which have shapes other than cylindrical. The majority of these sheets are very irregular in shape, and follow almost no law. The gusset sheet, perhaps, comes nearest to

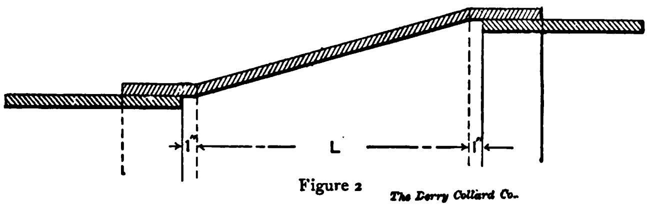


Figure 2 *The Derry Collard Co.*

Top portion of gusset sheet.

following a certain law, and even this sheet, although spoken of as being a section of a cone, is really a peculiar shaped cone, which instead of being circular at sections perpendicular to the axis, is circular at sections perpendicular to the center line of the boiler.

A gusset sheet which has the shape of a perfect cone is very easily developed. The bending line of the sheet when developed, can be struck by a radius from the center of the cone. The cases where this is used are very rare. The most common style of gusset sheet is shown in Fig. 1. The lower element being parallel to the center of the boiler, while the circular ends are at right angles to it.

The Development of the Gusset Sheet Shown in Fig. 1.

Fig. 2 shows the top portion of a gusset sheet. A flat portion for about an inch more than is required for the seam, is allowed at each end. The bending line of the sheet is taken equal to L in this figure. This corresponds to the L in Fig. 1. D is the front neutral diameter, and D° is the back neutral diameter. Strike semi-circles on these diameters, and divide them into any number of equal parts. In this case each circle is divided into eight parts. Continue the lower element, far enough, so that when the top element is continued they will intersect at some point, as O. This point is the apex of the cone, of which this sheet is a part. From O, with radii R and R°, strike two reference circles as shown in the figure. R° is determined by calculation as follows:

$$D^\circ : R^\circ :: D^\circ - D : L$$

$$R^\circ (D^\circ - D) = L \times D^\circ$$

$$R^\circ = L \frac{D^\circ}{D^\circ - D}$$

If the construction is being made to a smaller scale than full size, this distance R°, of course, will be measured with the same scale to which you are working. Project the points in these two circles upon their respective diameters, by placing the point of the compass on the lower extremity of the diameter, and then carry these points over radially as shown in the figure. From the point O with a radius equal to the arc O — 1 strike an arc as shown. From O° with a radius equal to the arc O° — 1° strike another arc, as shown, on the other side. The first element will be tangent to these two circles. Since the points in the circles have been projected into the plane upon which we are working, the true length of the first element will be the distance from 1 to 1°. These two points in the development, will be the same distance from the reference circle that they are now. Measure off the distance, therefore, from the reference circle to these points, and strike off these distances, to determine the developed position of the first element.

Strike off a new set of arcs, and then measure off the distance from the reference circles to the second set of points, strike another set of arcs from the reference circles, and determine the position of the second element. Continue this process until the eighth element is developed. When the seam is on the top center, this eighth element will be the center line of the sheet, and if continued, should also pass through the center of the cone. This is a proof of the accuracy of the construction.

The Development of the Gusset Sheet Shown in Fig. 3.

A very common form of gusset sheet is shown in Fig. 3. In this case the lower element of the gusset is not parallel to the center line of the boiler, which means that the circular ends will be inclined to this element, and the

Gusset sheet development.

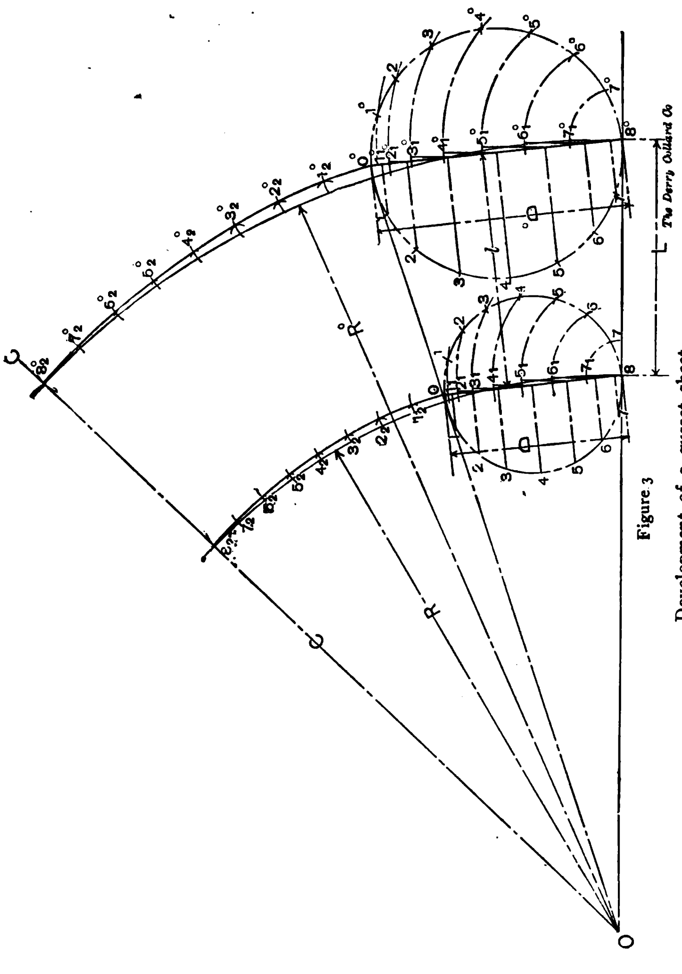


Figure 3

Development of a gusset sheet.

construction shown in Fig. 1 will not answer. Referring to Fig. 3, D is the front neutral diameter, and D° the back neutral diameter. The length l is usually an even figure, but the length L will be obtained from the right angle triangle, of which L is the hypothenuse, and l one of the sides. This can either be calculated or laid down to full size and accurately measured.

Knowing L, therefore, the length R° will be determined in the same way as in Fig. 1, and we will have

$R^\circ = L \frac{D^\circ}{D^\circ - D}$. The lower element is now continued

a sufficient distance to obtain the center. The continuation of the lower element, in any case, is very accurately done, by sticking a pin, or a needle, at the point 8°, and then stretching a thread from 8° through 8. By moving the thread back and forth, until it passes directly through the point 8, the center o of the cone, can easily be located on this line. Strike the two reference circles R and R°. Strike complete circles on D and D°, and divide each half of these circles in the same number of parts, in this case 8. Project the points on the right hand side of these circles radially on the diameter, and project the corresponding points on the left hand side perpendicularly on the diameter. For clearness in showing the construction, we will look at the small circle, and take the point 4 in the right and left hand side of this circle. From the intersection of the projected point 4 on the left hand side, draw a line at right angles to the lower element, until it intersects the arc 4–4_1, at the point 4_1.

In this same way, determine all the points 1_1, 2_1, 3_1, and so on. Also the points 1_1°, 2_1°, 3_1°, and so on.

Gusset sheet development.

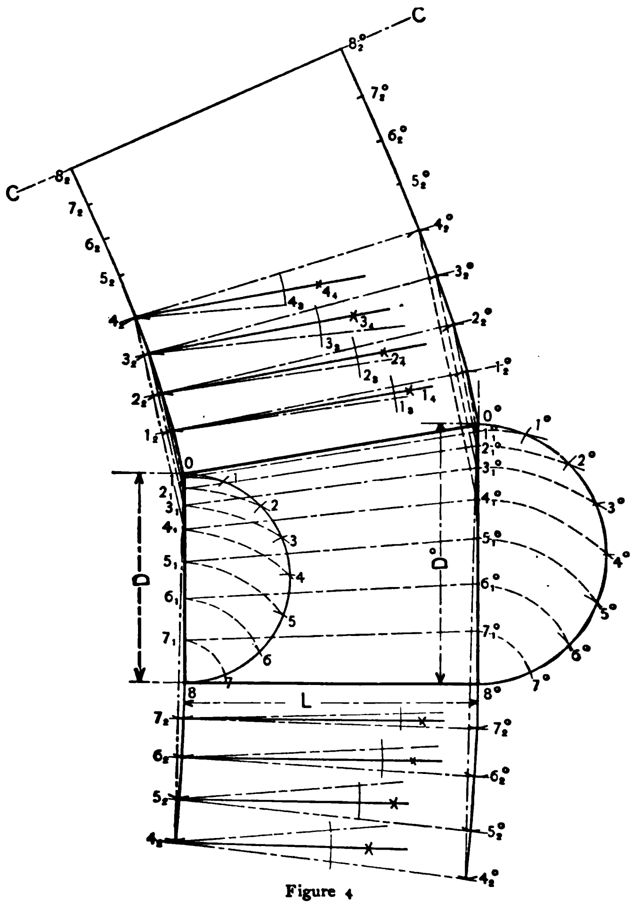


Figure 4

Development of gusset sheet whose center is inaccessible.

Gusset sheet development.

From o and o° as centers, strike arcs with radii o–1 and o°–1° respectively. Then measure off the distance from the reference circle to 1, and step this distance off and thus determine the point 1°. In the same way, measure off the distance from the reference circle to $1_1°$, and step this off, thus determine the point $1_2°$. We have then found the developed position of the first element. Strike off a new set of arcs and measure off the distances from the reference circles to the next points. Step these distances off and thus determine the position 2_2–$2_2°$. Continue this operation until the eighth element is developed.

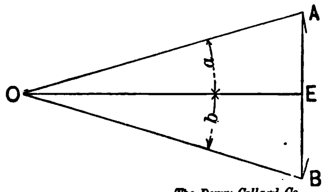
With the seam on the top center, this line will be the center line of the sheet, and if continued, will also pass through the center of the cone. If it does not, the construction has not been properly made.

The Development of a Gusset Sheet, Whose Center is Inaccessible. Fig. 4.

The following is a method for developing the slope sheet of a Locomotive Boiler, when the center from which the elements start is so far away that it would be impossible to operate a trammel stick of sufficient length to develop the sheet by the methods shown in Fig. 1 and Fig. 3. L is the length between bending lines of the slope sheet. D is the front neutral diameter, D° is the back neutral diameter. Upon these two diameters strike semi-circles as shown, and divide each of them into the same number of equal parts. Eight parts will be sufficient for all ordinary cases, as the difference between the length of the chord and the arc will not appear in the construction, as will be shown a little later.

Beginning at the slope line, with a radius o–1, and from 0 as a center, strike the small arc as shown. The length of this radius will be found by laying down the half circumference of the neutral diameter D (from a table) along a straight line; then having divided the line into eight equal parts, the length of one of these parts will be the radius, which of course will be exactly as long as the arc, instead of the length of the chord. From 0°, as a center, and with 0°–1_2° as radii, strike another arc as shown. The length of this arc will be found in the same manner as before. Draw the line 1_2–1_2° tangent to these two arcs. If this line is continued it will meet the line 1_1–1_1°, at the center, from which the elements begin.

Project the points 1, 2, 3, etc., and 1°, 2°, 3°, etc., upon their respective diameters, and then connect the



The Derry Collard Co.
Figure 5

corresponding points with straight lines as shown. Draw a line 1_2–1_3 parallel to 1_1–1_1° and bisect the angle between these lines by a line 1_2–1_4. This line will be parallel to the bisecting line of the angle made by the lines 1_1–1_1° and 1_2–1_2° as shown in Fig. 5.

If angle a and angle b are equal, and the line AB is drawn at right angles to OE, then O–A must be equal to O–B. Therefore, if through the point 1_1 and 1_1°

the line be drawn respectively at right angles to 1_2–1_4, the intersection with the two little arcs already struck will determine the developed position of the first element. From the two points just found, and with radii as before, strike off another set of arcs. Draw a line 2_2–$2_2°$ tangent to them, then draw a line 2_2–2_3 parallel to 2_1–$2_1°$. Bisect the angle thus made by a line 2_2–2_4. Then from $2_1°2_1°$ respectively, erect perpendiculars to this line. Their intersection with the second set of arcs will determine the developed position of the second element.

Continue the operation until 4_2–$4_2°$ is found. Commencing with the lower part of the figure, strike a set of arcs as before, then draw the tangent 7_2–$7_2°$ to them. Draw a line parallel to 7_1–$7_1°$, bisect the angle thus formed and from 7_1–$7_1°$ drop perpendiculars to this line; their intersection with the previous arcs will determine the developed position of the seventh element. Continue this operation until the position 4_2–$4_2°$ in the lower part of this development is arrived at. Then transfer this part to the top, making the lines 4_2–$4_2°$ coincide as shown. The eighth element will be the center of the sheet for cases where the seam is on the top center line. The other part of the sheet, when developed, will be symmetrical to the part here shown, and it is only necessary, therefore, to show this much of the sheet. If the seam does not come either on the top or the bottom center, the sheet will not be symmetrical but can be obtained in any case by measuring the distance from either the top or the bottom center line to the seam, and then laying off the corresponding distance on the development. The amount cut off from one side would of course be added to the other, thus maintaining the full length of the sheet.

Gusset sheet development.

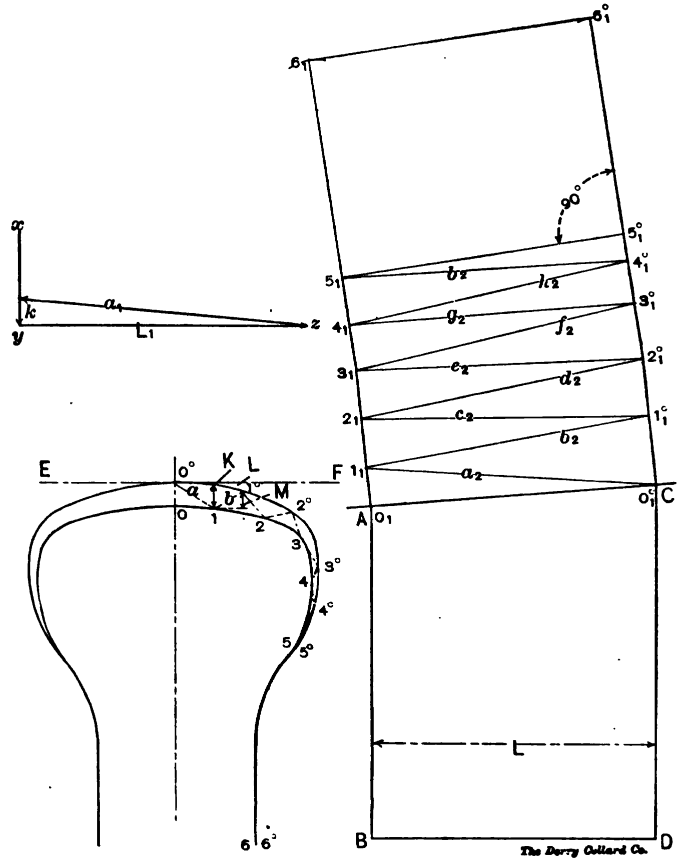


Figure 6

Development of irregular shaped sheet.

Development of irregular shaped sheet.

The Development of any Irregular Shape Sheet. Fig. 6.

Besides the gusset sheets, which have already been mentioned, there are other sheets which have such irregular shapes that they cannot be developed by any of the foregoing methods. Fig. 6 shows the method for developing any sheet, no matter what its shape may be. The example here taken is a fire box sheet. The crown and the side are in one continuous piece. The two views of this sheet as it would appear when bent, is shown in the lower left hand position of this figure. A–B is the back end and C–D the front end of the sheet. L is the length between the parallel ends. Referring to the left hand view, divide the outer and the inner lines of the sheet into any number of parts as shown. Connect these parts by the zigzag lines, as a, b, etc.

To develop the sheet, draw the center line o–o° and draw the line E–F through o° at right angles to the center line. Measure off the distance K from this line to the point 1, and then draw a right angle XYZ and make L_1 equal the length of the sheet. Lay off this distance K along XY and from the triangle thus formed get the length of a_1 with a pair of trammels. From o° as a center and with $a_1 = a_2$ as a radius, strike an arc. From o_1 as a center and with a radius $o_1 = 1_1 =$ o–1 strike an arc, cutting the previous arc at some point 1_1. This is one of the points in the development of the surface.

With a pair of dividers measure the distance for the line E–F to the point 1, and then transfer it to the point 1°, and subtract the distance L from it. This will give the distance M which will be laid off along XY. The hypothenuse of the new triangle thus found will be the length of a radius, which is equal to b_2. From the point 1_1 as a center and with this radius b_2 as a radius, strike an arc. From $0_1°$ as a center, and with a radius $0_1°-1_1° = 0°-1°$, strike an arc intersecting the previous one in some point $1_1°$. This is another point in the development of the surface.

In the same way as before, find the vertical height of the next zigzag line; measure it off along XY; take the length of the hypothenuse as a radius, C_2 and strike an arc with it from the point 1_1. With a radius $1_1-2_1 = 1-2$ strike another arc. This gives the point 2_1.

Continue this process back and forth, and find the points on each side of the development, until the position

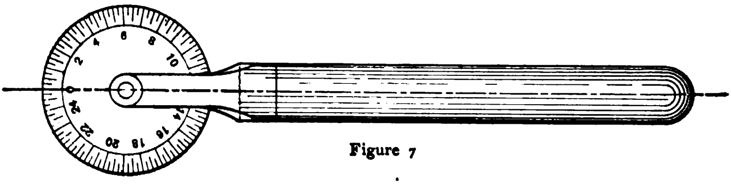
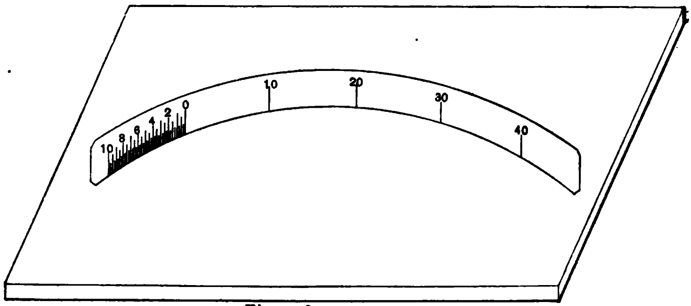


Figure 7

Wheel for measuring.

$5_1-5_1°$ is arrived at. At this position the front line and the back line of the sheet coincide in the left hand view, which means that the sheet is a rectangle below this line. Through 5 and $5_1°$ draw two lines at right angles to the line joining these points, and with a radius equal to the length along the curved line from 5 to 6, strike two arcs from 5_1 and $5_1°$ as centers. The points $6_1-6_1°$ will thus be determined. One half of the sheet is now developed, and since the figure is symmetrical the other half will be similar, A-C being the center line of the sheet. As a check upon the construction, the length of the developed line from o_1 to 6_1 should be exactly the same as the length of the neutral line of the sheet from o, around to 6, and the length of the developed line $o_1°–6_1°$, should be equal to the length of the neutral line of the sheet from o°



Figure–8

Paper measuring method.

around to 6°. In order to get these lines equal, a measuring wheel as shown in Fig. 7 is convenient.

If the sheet is laid down less than full size, which it frequently is, in a drawing room, this measuring wheel should be graduated to the same scale as the drawing. The outer edge of this wheel is beveled so as to form a sharp edge. The zero or o of the wheel is set to the o of the line of the sheet and the instrument run along the neutral line, the number of inches being noted. The instrument is then run along the development and the length of the lines must correspond. Indeed it is a good thing to check frequently as one goes along, as any error is then readily caught.

In the absence of one of these wheels, a paper scale

Laying out dome sheet.

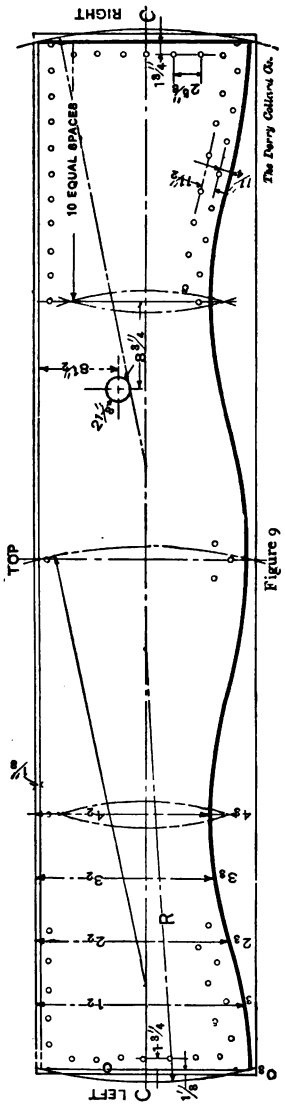


Figure 9

Laying out the sheet for body of dome as shown in Plate 4.

as Fig. 8, graduated to the same scale as the drawing, can be used. It is bent to coincide with the neutral line of the sheet and the length of the sheet transferred, the same as with the measuring wheel.

An example of quite a simple sheet will be taken from Plate 4. This sheet constitutes the body of the dome of this boiler. It will be noticed in referring to the plate that the dome base is of the common type, which is curved to the radius of the boiler. The sheet will also be seen to contain a seam, which is riveted together with welt strips inside and outside. The internal diameter is 30⅞ inches and the thickness of the sheet is $^9/_{16}$ inches. If the sheet is laid out on a flat surface, its length would be equal to the circumference of the neutral diameter, which would be $30\frac{7}{8} + {}^9/_{16} = 31{}^7/_{16}$.

From the table of circumferences, shown in the back part of the book, it will be found that the circumference of a 31¼ circle is 98.175, and also from this same table, the circumference of a $^3/_{16}$ circle is .589; the sum of these two will be equal to the length of the sheet, thus:

$$\begin{aligned} 31\tfrac{1}{4} &= 98.175 \\ {}^3/_{16} &= .589 \\ \hline 30\tfrac{7}{8} &= 98.764 = 98\tfrac{3}{4}. \end{aligned}$$

This is the length of the sheet.

With very few exceptions, the outside of the sheet is always placed up, and it is upon this side that all work is laid out. Bearing this in mind we turn to Fig. 9. One edge of the sheet here shown we will mark top and the right and the left side will be marked as shown. If this sheet is purchased, which is very apt to be the case, there will be sufficient metal allowed in ordering so as to project beyond the sheet somewhat, as indicated. With a long straight edge, draw the top line of the sheet one-eighth of an inch from the edge. This amount is necessary for planing. The height of the dome is 18½ inches at the narrowest part of the sheet; this is the figure usually given on the boiler card. There are two parts of

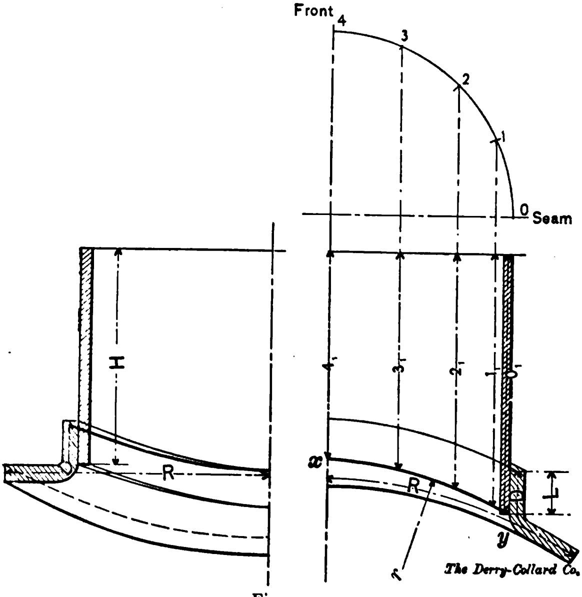


Figure 10

Dome base.

this sheet which have this width. The other part of the sheet is curved, and will be found by referring to Fig. 10. A half view of the cross and longitudinal sections of the dome are shown. H is the height already referred to, which is 18½ inches.

The dome base is circular inside and outside before flanging; after flanging, D in each one of these views, will be the same. The lap in this case is 3¾ inches and is laid off at L. A radius is now found of such length as will pass through x and y. The circle x–y, it must be remembered, is the neutral line of the lower edge of the sheet. With a radius equal to half the neutral diameter, strike off the quadrant of the circle, and divide this into four equal parts. Project these points 0, 1, 2, 3 and 4 upon the diameter, and draw the lines 0_1, 1_1, 2_1, 3_1 and 4_1. These lines represent the true length of the elements at the points 0, 1, 2, 3, etc. Having found these lengths, the curved line shown in Fig. 9 can be constructed. First lay off the length of the element 0_2 as just found on the right and the left hand side of this sheet. Bisect these lines and draw a center line C–C from one end of the sheet to the other. Now, with a pair of trammels, open to any radius R, strike the arc shown on the left hand side of the sheet, allowing about an eighth of an inch for planing. Then draw a line through the intersection of this arc with the top and bottom line of the dome sheet. This squares up one end of the sheet.

Along the top edge measure off the exact length of the sheet, as has been found from the table. Square up the other end of the sheet, by striking an arc as before and draw the line through the points thus found. With the trammels open to about half the length of this sheet, bisect the top line, and then with a radius as before, square a line across the sheet at this point. Then coming up on the center line, with a radius a little greater than one-fourth of the length of the sheet, strike the arcs as shown and draw a line through their intersection. This divides the sheet into four equal pieces. The sheet is now said to be quartered and every sheet should be.

Referring to the left hand side of Fig. 9, divide this quarter into four equal parts, and draw lines at right angles to the top line across the sheet. Measure off the length of the element for each one of these lines, from Fig. 10, and thus determine the points 0_3, 1_3, 2_3, 3_3 and 4_3. In the same way lay off the corresponding points in each one of the quarters. Then with a steel straight edge, bent to a curve so as to contain these points, and while the straight edge is being held, draw a line through these points, and then follow up the curve from end to end in this way. A very smooth line is thus laid out.

The rivets in the top part of the sheet will now be laid off. The drawing calls for 40 rivets; this number is divisible by four, and we will, therefore, have ten rivets in each quarter, one on each quarter line. With a pair of dividers, step off ten equal spaces in each quarter; it will be found that one of these rivets will come in the seam, and will be laid off the same way as the rest but will only be a half circle. If the holes are punched, a half circle will be punched at this place.

We will now lay off the rivets along the lower part of the sheet. This is a double riveted seam, and the drawing calls for 32 rivets. This number is also divisible by four, and as the drawing shows one of the rivets of the lower row on the center line, we will have a rivet on each one of the quarter lines. Draw two lines parallel to the lower edge, for the center line of these two rows of rivets. The first one being 1⅛ inches from the lower line, and the second 1½ inches from the first. There will be eight rivets in each quarter and here, as before, one rivet comes in the seam and will be laid off and treated in the same way.

Lay off eight equal spaces, along the lower line in each one of the four quarters. As the rivets in the top row are spaced a half a pitch ahead of those in the lower row, with a pair of dividers, lay off such a rivet midway between the other two. Then, having the dividers set to this distance, and taking the rivets already laid off in the lower line as centers, step along from one to the other, and lay off the rivets in the top line. The rivet holes are now all laid out except the vertical seam. There are seven equal spaces in this seam. Lay off a line at each end of the sheet at the required distance and divide this line into seven equal parts.

If it were not for one thing, the sheet thus laid out would be perfectly correct for the seam on the right or left hand side, but a whistle tap is required on the left hand side. Therefore this sheet to be correct for this case must have this on the proper side. The location will be as indicated in this figure. The tap is marked $2^5/_{16}$ with twelve thread. We must therefore drill about a $2\frac{1}{8}$ hole at this point. This completes the dome sheet.

Dome Base.

The dome base, Plate 4, is made from $1\frac{1}{8}$ steel plate. The material will come from the mill sheared very nearly round, and having enough metal allowed on the outside to true up nicely. Fig. 11 shows this sheet. It is circular, of a radius R and when bent R_1–R and D_1–D are equal. The center of the sheet is determined by striking several arcs of equal radius from the outer edge of the sheet. The center having been determined, a circle is struck with $R_1 = R$ as a radius. Lay off $D_1 = D$ and strike the radius r_1. The sheet is now ready to be turned off along the outer edge, and cut out in the center. It is then ready for flanging. No holes will be put in this sheet before flanging.

Dome Flange.

Referring to Plate 4, it will be seen that the dome flange is also made of 1⅛ steel plate. There is usually a special card showing the detailed dimensions of the

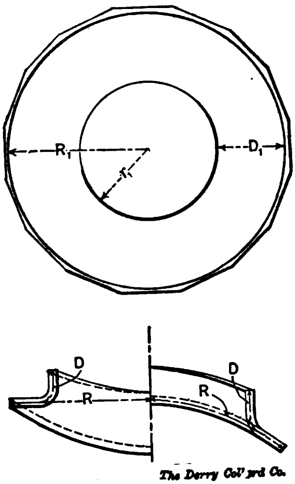


Figure 11

Dome base.

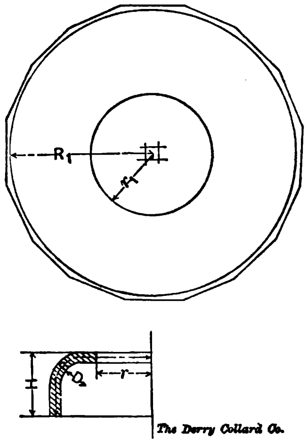


Figure 12.

Dome flange.

dome flange and dome base, and the figures which are omitted on this drawing would be shown on that card. The height of the flange H, Fig. 12, would be laid off, and the proper dome radius sketched in to suit. The dome card would give the dimension for the radius D of the corner. Thus having laid down this sheet full size, the run of the neutral line R will be obtained with the wheel. This is equal to R_1.

The sheet as it comes from the mill, would be a little larger than the circle of this radius. The center of the sheet will be found and the outer circle struck. The inner circle will now be laid off with a radius r_1, which will be taken from the detail card. This sheet, unlike the dome flange already described, will not be machined on the outer edge, until it is flanged. It might also be mentioned that when a dome is like that shown in Fig. 12 the inside has some metal allowed for finishing after the dome base is flanged. The treatment of this particular dome will be mentioned in another chapter.

First Course.

Again referring to Plate 4, it will be seen that the first course in this particular boiler extends through and is attached direct to the smoke box sheet, instead of having a ring at this seam, as is the case with the boiler shown in Plate 3. This is a cylindrical sheet, and when it is laid out on a flat surface it will be rectangular. The sheet which will be used for this case will have an allowance on the sides and ends. Begin to lay out the work on the side of the sheet containing the maker's name and also the tensile strength of the test piece. This side will be out when the sheet is rolled. With the straight edge draw a line at about 1/8 inch from the lower edge of this sheet as shown in Fig. 13. Next, from the table of circumferences, find the length of the neutral diameter of the sheet. The drawing shows the internal diameter of this sheet to be 66 inches, and the thickness of the sheet

Laying out the first course sheet.

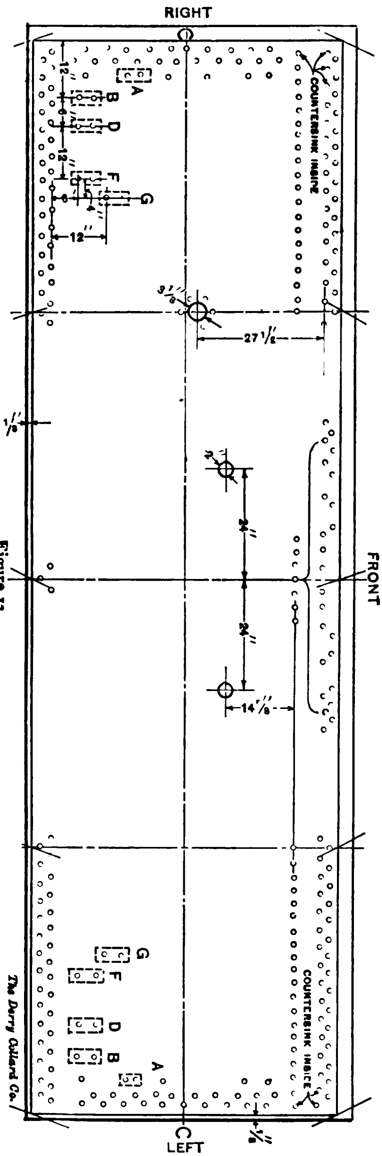


Figure 13

Laying out the sheet for first course of boiler shown in Plate 4.

is $^{23}/_{32}$ inch. This makes the neutral diameter $66^{23}/_{32}$ inches. Look up the following figures in the table, and arrange as follows:

66½	dia.	=	208.916	cir.
$^{3}/_{16}$	"	=	.589	"
$^{1}/_{32}$	"	=	.098	"
$66^{23}/_{32}$	dia.	=	209.603	cir.

This will be the exact length of the sheet. Measure off this distance along the lower line, and see if the sheet is of sufficient length. Allow about ⅛ inch along one of the ends for planing, in this case the left hand end and then on this line, lay off the width of the sheet which is 66 inches. Draw the top line with a straight edge through these points. Next, bisect these cross lines at each end of the sheet, and draw the center line C–C from one end of the sheet to the other. Measure up the sheet for width and length, and also measure to determine whether C–C is in the center of the sheet, so as to be sure that everything is correct.

In fact this idea of checking the work is to be continued all through the process of laying out, else one is apt to do an enormous amount of work and then find out that some mistake has been made, in a certain figure, upon which all the other work depends. One cannot be too sure that everything which has already been laid down is correct, and it is for this reason that continual checking should be resorted to. Having therefore located the center line, with a large radius, and with a center on this line, strike off the arcs at each end of the sheet, through the end points along the lower line. This squares up the sheet.

With the trammels, either on the center line, or on the top or bottom line, bisect the length of the sheet. Square a line across the sheet at this point. The sheet is now divided into two equal parts. Next, bisect each one of these parts, and square lines across the sheet at these points. The sheet is thus quartered. The drawing shows that the seam is required to be placed on the top center. The front of the sheet is the top of Fig. 13, and the right and left hand sides of the sheet are also marked.

Beginning with the front double row of rivets we find that the drawing calls for sixty rivets, and also shows the front row beginning on the side center. As there are sixty rivets, there will be fifteen in each quarter; one on each center line. With a pair of dividers, step off fifteen equal spaces in each quarter. This can be done, as is very frequently the case, by setting the dividers about right, and then stepping off the fifteen spaces, doing a little adjusting on the dividers to make up for the amount of error, and then trying a second time.

These rivets are sometimes laid off by a process which is very accurate, and frequently a great deal easier than stepping off a lot of points. It consists in dividing up the number of spaces into its factor, and then laying off in this way: Taking the case of the fifteen rivets just mentioned, the factors of fifteen are five and three. The space is first divided into three equal parts, and each one of these parts is subdivided into five. Or the distance is first divided into five parts, then each one of these parts is divided into three. The method will readily be understood and can often be used to advantage.

Having thus laid out all the rivets along the first row, those on the second row are spaced half a pitch from these rivets, and will be laid out with a pair of dividers set equal to the diagonal distance between two of them.

Laying out the first course sheet.

Step along the first row of rivets and lay out the second row from end to end. In the same way, lay out the two rows in the back of the sheet, the number of rivets being the same. The back row of rivets begins on the center line and all the other rivets fall in to suit. Of course, the center line for these rivets will be laid off at their proper distance from the edge of the sheet, according to the figures shown on the drawing. The next thing will be to lay out the rivets for the tube sheet. These are eighty in number and begin on the center lines, twenty in each quarter. These rivets will be stepped off in the same way as before, along a line 9½ inches from the front edge. The rivets in the butt seam will next be laid out. Draw three lines along the left hand edge at the proper distance from the edge to suit the figures shown on Plate 4. There are twelve equal spaces between the tube sheet row and the front row of the back seam.

These equal spaces will be laid off along the second line. The rivets in the first line will be spaced midway between them and stepped off with a pair of dividers from the second row. The third row will be on a line with the first, and will have half as many rivets as either one of the other two lines. One rivet of the third line extends through and takes the foot of a stay rod; another rivet, three inches from it, also goes through this same foot. In a similar manner lay off the rivets on the right hand side of the sheet. Also locate the two rivets along the third line, on this side of the sheet, to take the foot of the stay rod A. The stay rod B takes two rivets, which are placed six inches and nine inches from the front row of the back seam.

Referring to the front tube sheet it will be seen that, when the stay rod B is thrown out radially, it will strike the sheet at twelve inches from the center. In the same way D would be located six inches further around, F six inches from D and C four inches from F. The location in the other direction will be to suit the drawing, which is six and twelve inches.

In the same way lay off the rivets for B, D, F, G, on the left hand side of the sheet. Two 2½ inch wash-out plugs are required in the waist, 24 inches on each side of the bottom center and 14⅝ inches back of the front tube sheet rivets. These holes will be drilled about 2 inches in diameter. The drawing also calls for a half inch liner on the right hand side of center, 27½ inches from the back row of the front seam. The hole will be drilled about 3⅛ inches diameter and 6 rivets laid off, beginning on the side center. This will complete the work of laying out the sheet. The holes marked X and Y, Plate 4, being in the same seam, will either be half punched or will be drilled after the sheet is bent and bolted together. T is a tap about ⅞ or an inch in diameter and fills up the space between the welt strip and the slope sheet at this seam.

One other thing should be mentioned before leaving this sheet. By referring to the drawing, it will be noticed that the cylinder flange projects over this seam, and also that some of the cylinder bolts come in the line with the front row of rivets. The holes as they will appear in this sheet are shown in Fig. 13. Those indicated by the bracket will have to be countersunk on the outside of the smoke box sheet, in order to clear the cylinder flange. The holes for the cylinder bolts will not be put in the sheet until the boiler comes in the erecting shop. Then the holes will be drilled through the cylinder flange and through the sheet at the same time. Some however, put the cylinder bolt holes in the sheet before it is bent. In this case the sheet and flange must be laid down and the lengths taken with the wheel along the neutral line.

Front Tube Sheet.

Fig 14 is the front tube sheet of the boiler shown in Plate 5. The flange is 4 inches high. Before flanging,

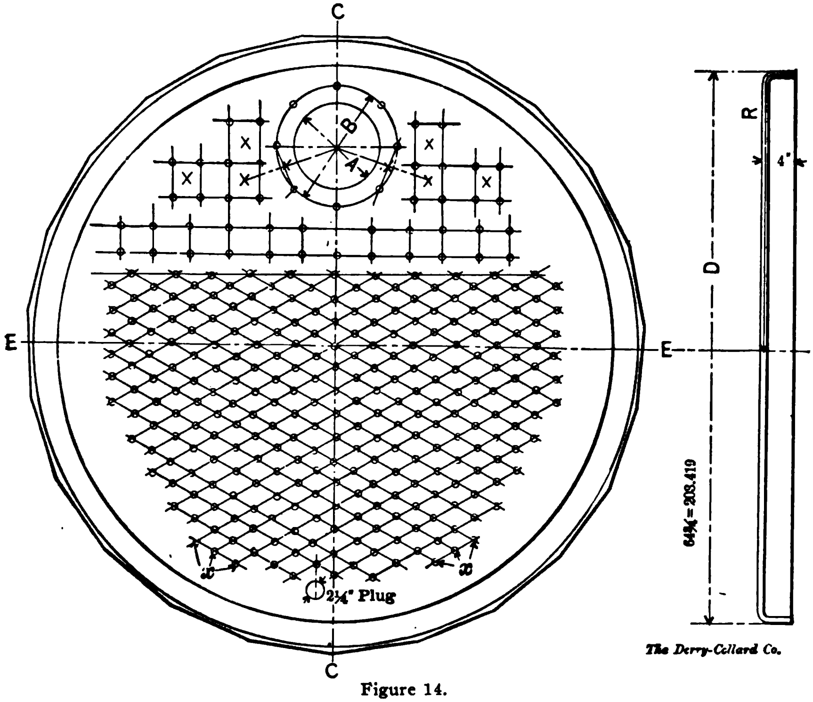


Figure 14.
The front tube sheet.

this sheet should be a circular plate of a diameter D = twice the length of the neutral line R. In addition to this diameter, sufficient metal must be allowed for turning off the edge of the sheet after the plate has been flanged. The center of the sheet will be found with a pair of trammels, by striking arcs at the center from several points along the outer edge. Then draw lines C — C and E — E at right angles to each other through this point. There are 264 tubes, and the figures marked front are to be used on this sheet. From the horizontal center line, measure off the distance 8¼ inches above and 27½ inches below. And from the vertical center line, measure off 26¼ inches on each side.

There are 13 equal spaces vertically and 11 equal spaces on each side of the center. Space these distances off along the center lines and then, through the points thus found, draw the inclined lines as shown in Fig. 14. Having drawn these lines, and keeping the drawing before you, mark out the limiting tubes with the soapstone pencil. Having laid out these limiting tubes on both sides of the center, the rest of the work will be easy enough. A 2¼ inch plug is shown on the drawing, placed on the right hand side only. Its location vertically will be such that the outside of the thread will maintain the same thickness of bridge as between the tubes.

All the tubes being laid off, they are center punched. The usual practice, as to punching the holes for these tubes, is to be put in about a ⅞ or 1 inch hole, before the sheet is flanged. The exception in this case, would be the three holes marked X on each side of the center. These would be drilled after flanging on account of the liability of these holes drawing when the sheet is being flanged. There are some places however where the sheet is flanged, then laid out on the inside, and after this, the holes are punched about $^1/_{16}$ of an inch under size, then reamed out to the required diameter.

The part of the sheet above the tubes is stayed, and the holes will be laid out from the figures shown on the drawing. The first row of holes will be eleven inches from the center line, and the second row, three inches from this. The rivets will be pitched 4¼ inches the other way. Next, the two vertical rows of rivets can be laid out, being 9½ and 11½ inches on each side of the center and spaced vertically to suit the T iron. The four rivets on each side of these two rows will be laid out in the same way and spaced the same way to suit its T iron. There is a stay shown attached to the inside of the tube sheet ring that will take two of the rivets which hold the ring in place. In this case, they will be spaced, 13½ inches in diameter and they will be pitched 8 to the circumference.

The hole for the dry pipe will be shown on a special drawing and in this case would perhaps be 10 inches, having the greater part of the sheet beveled off for a ball joint. All the rivet holes shown in this sheet can be punched.

Those shown in the tube sheet ring, if they are rivets, would also be punched to suit. If they were tapped, which is frequently done, the holes would have to be punched small enough to ream out and tap. The same tap would also extend into the ring. The holes for the eighty rivets in the flange will be laid off after the sheet is flanged and turned off along the outer edge. The tube sheet is to fit a 64-inch diameter and the circumference corresponding to this is 203.419. This must be punched on the sheet so that when it is flanged, the rim can be made to suit this figure.

The smoke box sheet.

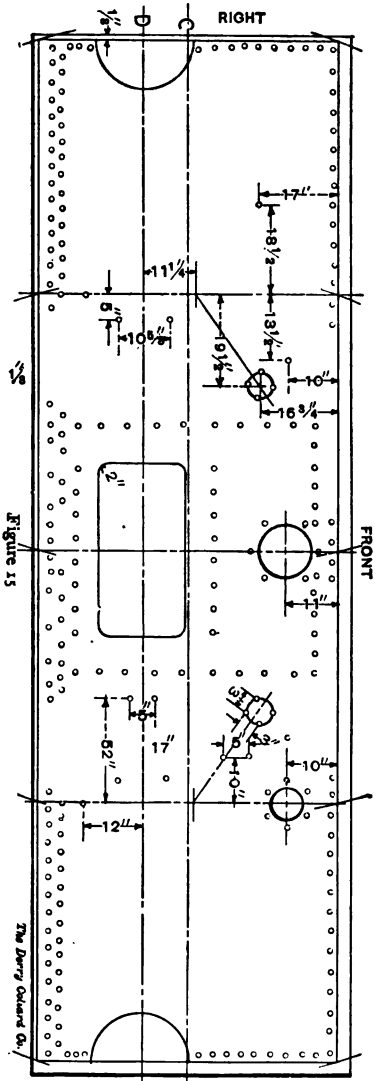


Figure 15

Laying out the smoke box sheet of boiler shown in Plate 4.

The Smoke Box Sheet.

The smoke box sheet shown on Plate 4 is laid out in detail in Fig. 15. This sheet has a liner in the bottom for the purpose of strengthening the sheet of the boiler at this point, for connection to the cylinder. The front end of the boiler has a wrought iron ring riveted as shown. The back end is attached to the sheet shown in Fig. 13. Referring to the drawing, the inside diameter of this sheet is $67^7/_{16}$ inches and the sheet being $\frac{1}{2}$ inch thick, the neutral diameter will be $67^{15}/_{16}$. The circumference will be found from the table thus:

$$\begin{array}{rl} 67 \text{ dia.} = 210.487 & \text{circumference} \\ {}^{15}/_{16} \text{ dia.} = \quad 2.945 & \text{circumference} \\ \hline 67\,{}^{15}/_{16} \text{ dia.} = 213.432 & \text{circumference} \end{array}$$

In Fig. 15 this sheet is shown with the usual allowance for trimming up the edges. Draw a line along the lower edge of this sheet from one end to the other, allowing about $\frac{1}{8}$ of an inch for planing. The width of the sheet is $63\frac{1}{2}$ inches. This distance must be measured off on each end of the sheet and the top line drawn through these two points, thus forming the two edges of the sheet. The length of the sheet is now measured off along one or the other of these two lines, and the right hand side of the sheet (in this case). is drawn close to the edge, allowing sufficient metal for planing. The center line C–C of the sheet is now drawn and the ends of the sheet squared up as before. Also the cylinder center line D–D is also drawn through the whole length of the sheet.

In reference to these two lines, care must be taken so as not to get the dimensions measured off from the center line of the sheet, instead of the center line of the cylinder. The front row of rivets is shown 1⅛ inches from the edge. A line will therefore be drawn at this distance along the front edge of the sheet. The drawing calls for 52 rivets, giving 13 rivets in each quarter. They are shown spaced between the centers, so take any one of the lines and lay off 13 equal spaces in one-fourth of the length of the sheet. Set the dividers to this distance and space half this amount on each side of one of the quarter lines, and then step off 13 equal spaces in each quarter.

The back seam will be laid off in exactly the same way as the corresponding rivets in Fig. 13, except that the spaces in this case will be a little larger, owing to the neutral diameter being larger. Fifteen equal spaces will be stepped off in each quarter, beginning the front row of rivets on center. Those rivets included with the bracket will have to be countersunk on the outside of this sheet, to clear the cylinder flange. The cylinder bolt hole will not be put in.

The seam of this sheet, not having to withstand any pressure, is a butt seam, and is single riveted, with a welt strip inside only. These rivets are shown 1⅜ inches from the edge of the sheet and the figures are given for the rivets on each side of the smoke stack opening. The remaining rivets will be equally spaced. All these rivets will be countersunk outside.

The smoke stack opening can now be laid off. It is to be 21 inches in diameter, and will be a semicircle on each end of the top center line as shown. These circular ends will be punched out, and the edges chipped smooth. The cylinder opening is required to be central and will be laid off to the figures on the drawing. A circular hole 10 inches in diameter and 11 inches from the front, will be laid off on the bottom center line. Also two rivet holes, one front and one back, on the bottom center line and two holes on each side of the center, to the figures shown.

The opening, 10 inches from the front edge on the left hand side center, can now be laid off. The holes will be six in number, being central with the line parallel to the front. The four holes shown 16¾ inches from the front, are for the smoke box brace. The inclination of the center line of these rivets is figured and will be laid down on the sheet on the right and left hand side to suit. A circle of five inches diameter is struck, and the four rivets located according to the figure, keeping the first two rivets central with the center line and measuring off the other two from these. Several sets of holes are required for brackets, etc., and will be laid off on one side or the other or on both sides, according to the figures noted on the drawing. The opening for the cylinder will be punched out and chipped smooth, while the other two circular holes will be drilled out by some form of radial drill.

Dome Course.

The dome course shown in Fig. 16 is the development of the sheet on Plate 4. It will be seen that this sheet, unlike those that have just been described, is cut out, for a portion of its length. For this reason and also for the purpose of showing the connection of the dome, this sheet has been selected. There is also one other thing which is different from any other sheet thus shown. This is the seam, not being on one of the four center lines. The seam is shown 9 rivet spaces to the left of

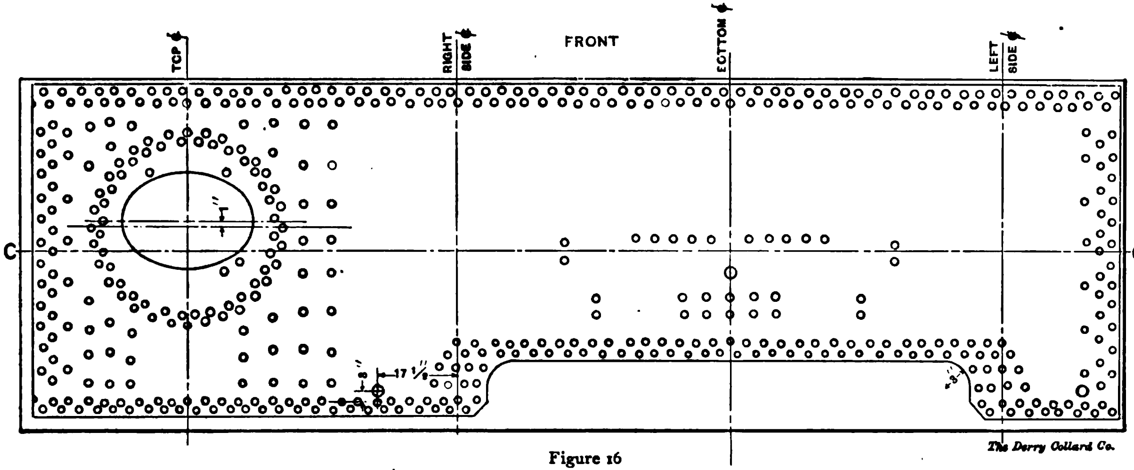


Figure 16

Laying out the dome course sheet of boiler shown in Plate 4.

the top center. As there are 64 rivets in one row of the front seam, there would be 16 rivets in each quarter. Having laid off a line equal to one-fourth of the circumference of the neutral diameter, divide this line into 16 equal parts, and with the dividers thus spaced, step off nine of these parts, to the left of the top center line; this will be the distance that the seam will be from the top center.

The neutral diameter of this sheet is 75 inches and the circumference is 235.62. This distance will be laid off along the sheet, allowing a sufficient amount for planing along one edge. Along the top of Fig. 16 a line is drawn also allowing enough metal for planing. The width of the sheet, which is $70^{13}/_{16}$ inches, will be laid off at each end of the sheet from this line, the other edge of the sheet being drawn through these two points. The width of the sheet will be bisected and with the straight edge a center line C–C is drawn. From this center line, and with a liberal radius, square up the ends of the sheet.

Now, from the left hand edge of this sheet measure in a distance equal to 9 spaces of the rivets and draw the top center line across the sheet perpendicular to the line C–C. From the right hand end of the sheet measure back a distance equal to 7 spaces of the rivets and square a line across the sheet at this point. The two portions measured off, at each end, must together equal one-quarter of the sheet. The remainder of the sheet must be equal to the other three quarters and the distance between the two center lines already drawn must be divided into three equal parts and lines squared across the sheet through these points. The top center line has already been marked and the bottom center line must, of course, be two "quarters" of the sheet from this.

Remembering that the work is to be laid out on the outside of the sheet, the right side center line and the left side center line will be seen to conform to Fig. 16. Two lines will now be drawn parallel to the top of the sheet at their proper distance from the first and second row of rivets, and as there are to be 16 rivets in each quarter, these rivets will be spaced to suit. The drawing shows that the second row of rivets will commence on the center line. Having laid off all those in one line, the rivets in the other line will be stepped off by a pair of dividers, so as to bring the rivets one half a pitch ahead of those in the other row. Draw two lines parallel to the lower edge at their proper distance from the edge, and from the first and second row of rivets, for the back seam.

The drawing calls for these rivets to be spaced 3½ inches pitch, and stepping this distance off we find that it will come very close to 16 spaces. We therefore make the front rivet central in this seam and lay off 16 equal spaces. This would be done in the quarter to the right of the top center line, and with the dividers set to this space the rivets will be laid off on the other side of the top center line and also the rivets shown on the right hand end of the sheet. The lower part of the sheet is shown cut out, making the sheet narrower on the bottom than on the top. The width of this sheet is laid off along the bottom center line and a line drawn for the edge of the sheet. Two other lines for the rivet centers are also drawn at their proper distance from the edge. As shown, 16 rivets will be placed in each quarter. The connection of the throat sheet with the dome course is shown on this drawing and has two rows of rivets between the parallel rows already mentioned, and four rivets spaced in each row. These rivets will be placed in the sheet as shown.

The corners of the sheet will be beveled off to suit the inclination of the rivets along the lower seam and a three inch radius struck as in Fig. 16. The rivets for the dome flange will now be laid off. The dome is located 37½ inches from the front row of rivets in the back seam and the opening in the sheet is located one inch in front of this center line. The opening is shown elliptical and is to be 22 x 28 inches. Four rivets are located near this opening, two in front on each side of the center line, and the other two back on the right side only.

From the dome card, the radii of the two rows of rivets around the dome can be obtained. Strike these circles from the dome center (not the center of the hole). Eight rivets are required in each quarter and the outer row comes central. Two lines of rivets are shown, one on each side of the dome. The rivets for this liner are all located on the drawing. These rivets will now be laid off to suit the figures. The rivets for the seam can next be laid off. Draw three lines parallel to the left hand edge of the sheet at their proper distance for the rivets, and step off fourteen equal spaces between the back row of the front seam and the front row of back seam. The rivets in the first and the second row of the seam will be staggered. The rivets in the third row will be half as many and placed in line with those of the first. The rivets on the left hand side of the sheet will be laid off in a similar manner. A 2¼ plug is required on the right and left hand side of this sheet, and they will be three inches in front of the front row of rivets in the back seam and 17½ inches up from the side centers. Five holes are required on each side of the center for the waist sheet angle

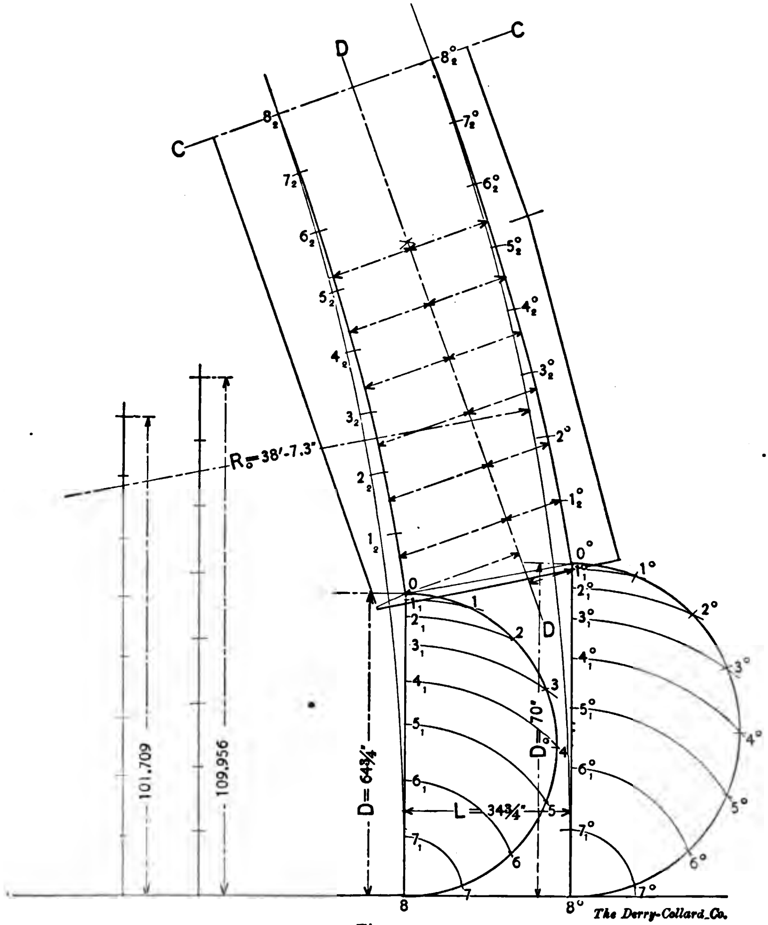


Figure 17

Development of gusset sheet shown on boiler in Plate 2.

iron, also a 2¼ plug on the bottom center line. These holes for the plugs must be drilled about two inches in diameter, as the sheet in bending will open up somewhat on the outside.

In the end view of the boiler, Plate 4, it will be seen that nine throat stays are shown. These stays will be attached to the dome course and holes will have to be put into this sheet for them. They are laid off in Fig. 16 as they should appear on this sheet.

Gusset Sheet.

The gusset sheet shown in Plate 2 will next be developed. It will be noticed that this sheet belongs to that class of gussets where the lower element is parallel to the center line of the boiler, and as the slope of the top element is considerable, this sheet can be developed by the method shown in Fig. 1. The front neutral diameter is 64¾ inches, and the back neutral diameter is 70 inches. The distance between the bending lines of this sheet will be 34¾ inches. These dimensions are laid down to scale in Fig. 17. Continue the lower element far enough to contain the center of the cone. R° will be obtained thus:

$$R^\circ = L \times \frac{D_0}{D_0 - D}$$

$$= 34\tfrac{3}{4} \times \frac{70}{70 - 64\tfrac{3}{4}} = \frac{139}{4} \times \frac{70}{5\tfrac{1}{4}} = \frac{139 \times 70 \times 4}{4 \times 21}$$

$$= 463.33 \text{ inches} = 38 \text{ feet } 7.3 \text{ inches.}$$

Use a trammel stick of sufficient length to take in this distance, to whatever scale the drawing is being made. In this case perhaps, the scale would be 3 inches to the foot. The dividers having been accurately set to this distance and the center determined. The two reference circles shown in Fig. 17 will be struck. Strike semicircles on D and D_0 and divide them into eight equal parts. Project these points upon the diameters and number them as shown in this figure. From the table of circumferences, get the half circumference of a 70-inch circle, which will be found to be 109.956, and lay down a straight line of this length. Bisect the line, bisect each one of the halves and each one of the quarters. This line will then be divided into eight equal parts. In the same way the half circumference of 64¾ inches is found to be 101.709, which is laid down and also divided into eight equal parts. A second pair of dividers is set to one of these parts. With these two dividers and from O and O° as centers, strike the corresponding arcs as shown in Fig. 17. After a set has been struck, the distance from the measuring circles to the proper projected points 1_1 and $1_1{}^{\circ}$ is transferred to these arcs, thus determining the first two points in the development. A new set of arcs are struck from these points and a new set of distances measured off, thus determining two more points. This process is continued until the center of the sheet C–C is arrived at. This sheet is symmetrical because the seam is on the top center. A line D–D is now drawn at right angles to the center line and is used as a reference line. Dimensions, as shown, are laid off and the figures at these respective points are obtained by measuring off the distances with a scale.

In a great many instances this part of the work would be done in the drawing room and the figures for the gusset would all be given on the boiler print, or on a special card. The distance from the bending line to the edge of the sheet, which in this case will be 6½ inches back and 6¼ inches front, will be laid off from the development here shown. An allowance of about a quarter of an inch each side will be sufficient for the size of the sheet. The sheet as it comes from the mills is sheared, as shown in Fig. 17. It must be remembered that this only shows one-half of the sheet; the complete sheet is shown in Fig. 18. Having now finished the construction and determined the figures which will locate the development from a reference line, we will now begin the work of laying out the sheet as in Fig. 18.

Stretch a line D–D from one end of the sheet to the other at about the position where you think the reference line belongs. While the line is held in this position, measure off with a rule at the ends the proper distances for the limit of the sheet and then shift the line D–D so that the best position will be obtained. Having settled on these distances at the end, measure up the sheet in the middle to see if the reference circle has been properly located and to make sure that when the work is laid down it will not run off the plate. Now with a straight edge, draw the reference line D–D. Bisect this line and draw the center line C–C at right angles to it. Along the center line D–D lay off the dimensions which have already been decided upon, in Fig. 17.

The first distance will be rather large, for the reason that the curve around the bottom center is very flat and the dimensions will hardly be measurable for a distance of about 2 feet. From this point, with spaces 4 or 6 inches, draw lines corresponding to the location already decided upon, at right angles to the reference line; on these lines lay off the proper dimensions. A similar construction is made on the left hand side of the sheet, and

Laying out the gusset sheet.

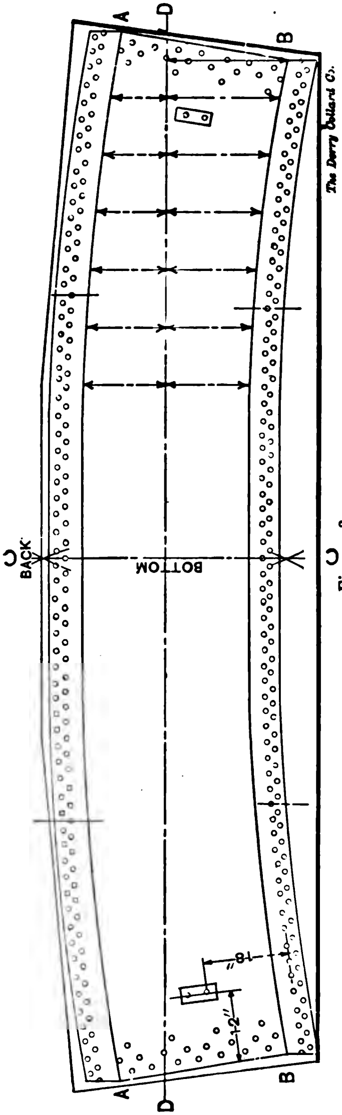


Figure 18

Laying out gusset sheet of boiler shown in Plate 4.

through the series of points thus laid out draw a curved line with the aid of a straight edge bent so as to strike the mean position of the points. The lines which have thus been laid out are A–A and B–B. Beginning with the line A–A and with the dividers set to 6½ inches, strike a number of little arcs, which when connected will give the top edge of the sheet.

In the same way, with the dividers set to 6¼ inches, draw the lower edge of the sheet. At the top of the sheet draw two lines, the first 1¾ inches from the edge, and the second 2 inches from the first. The sheet must now be quartered for the top seam. The points A and A will be located from the dimensions already obtained. As this is the neutral line, the neutral circumference at this position A–A will be exactly the same as it would be at the edge of the sheet. Therefore when this gusset is rolled and the outer edge closed in the proper amount, the lines of the butt seam at this point will coincide. In the development the sheet from the points A–A to the edge will be parallel with the center line. In Plate 2, it is seen that 64 rivets are required in the back seam. There will therefore be 16 rivets in each quarter. As the drawing calls for the rivets on the inner rows to be on the center, the second one of the two rows of rivets on the top sheet will commence on the center line. Bisect the length of the half of the second line of rivets on each side of the center line, thus dividing the length of this line into four equal parts. Then either step off 16 equal spaces in each quarter, or bisect each quarter and bisect each one of the remaining parts, dividing the sheet into 16 spaces in each quarter. The outer row of rivets will be spaced half a pitch from these.

In the lower part of the sheet the length of the neutral line B–B is the same as the length of the neutral line on the front edge at the gusset sheet. Therefore the edge of the sheet at the point B will be parallel to the center line. The second row of rivets will commence on the center and will also be spaced into 16 parts as the drawing calls for a total of 64 rivets. The outer row of rivets will be laid off from these. The drawing calls for 4-inch spaces for the rivets in the butt seam. The line will be laid off at each end of the sheet corresponding with the figures on the drawing.

The distance between the inside rows of rivets is such that nine equal spaces will be very nearly 4-inch pitch. Extend the second line to the inside rows and then space this into nine equal parts. The rivets in the first row are spaced half a pitch from these. Those in the third row are on a line with those in the first but only half the number. Continue the same process at the other end of the sheet and lay out the rivets there. Of course the studs for the bell and those for the sand box would have to be obtained from the detailed cards, and if they came so that it were possible to put these holes in the sheet before bending, they would be laid off to suit.

In the front tube sheet in Plate 2, it will be seen that four stay rods are required. Of these, three will swing nicely against the side of the first course, but the fourth had best be carried back and thrown against the side of the gusset sheet. The distance from the center will be 12 inches and its distance back can be settled upon as being 18 inches. A pair of rivets will thus be laid out to suit the foot of the stay rod; these being of course on each side of the top center. The sheet is now complete as far as this drawing is concerned. There will, however, be detail cards which will have to be looked up and if any other holes are required in this sheet, they will be laid down to suit the figures on those drawings.

Side Sheet.

The boiler shown in Plate 3 is of that class having the throat sheet running back at an angle, the idea being to get the center of gravity of the boiler somewhat further ahead so as to give a better distribution of the weight upon the drivers. The back end of this boiler is also at an angle. This gives more room in the cab, although it makes a boiler which is very difficult to build. The side sheets of this boiler have been selected on account of its being considerably more difficult than the general run of these sheets would be. This sheet is shown in Fig. 19 and will come from the mill sheared along the outer edge somewhat as here shown.

Draw a line along the top of this sheet allowing a sufficient amount of metal for planing. This will be the line of the butt seam. The drawing calls for this seam to be 24½ inches above the center line. This is the length of the neutral line of the sheet from the center to the seam. The slope of the outside crown sheet is 3 inches, and therefore we may take 21½ inches as the distance from the center line to the seam, on the back end of the sheet. Lay off these distances and draw the center line C–C. The lower edge of this sheet stands away from the bottom of the water space frame ⅛ of an inch in order to allow calking the sheet. This brings the distance from the center to the lower edge of the sheet 46⅞ inches. Lay off this distance on the left hand side and also on the right hand side and draw the bottom line of the sheet. This will be parallel to the center line. If this sheet comes

The side sheet.

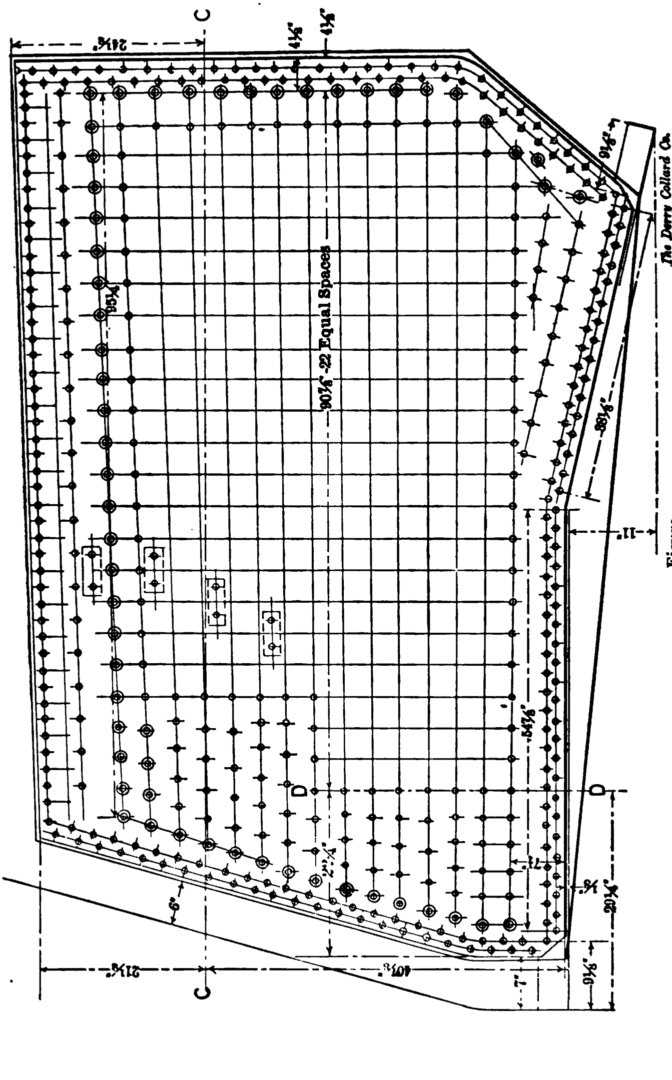


Figure 19

Layout of side sheet of boiler shown in Plate 8.

in with very little allowance, you will not have room enough to lay off the lines which run at an angle. For this reason, take a somewhat larger sheet and lay off the back part of the boiler full size on it, the back head at its proper angle and the water space frame to suit the figures.

This will also be useful in connection with the throat sheet, the location of stays, etc. Also lay off the view shown to the left of the rear end of this boiler. The stay bolts will be laid off front and back on this full size view to suit the figures on the drawing. This is also used to ascertain whether everything is all right.

It frequently happens that a few of these dimensions are not correct and it may not be the fault of any one perhaps, as these dimensions were measured from a drawing which was $\frac{1}{8}$ or $^1/_6$ of the full size. If any dimensions should be found in error, one way or another, they will be corrected on this full size view. Having made these two constructions, we can proceed with the work of laying out the sheet in Fig. 19.

The back edge of the sheet is shown 6 inches at one place, from the inside line of the back head, and 7 at another. These lines will be drawn at the proper angle to each other and to the center line. In order to get this angle, measure off a distance 4 feet in the large view already referred to. Then having drawn a line through the one extremity of this 4-foot line, measure the distance to the other end. Transfer this distance to Fig. 19 and draw the line through the points thus found. In the same way the lower part of the sheet, which slopes along the water space frame, will be laid off and in a similar manner, the line along the seam for the throat sheet. The front line of this sheet will be located to suit the figures obtained from the full size view and will be at right angles to the center line. The outside edge of the sheet will thus be located all around and measured up to be sure that everything is correct. Beginning with the top line of the sheet, draw a line parallel to this edge and 2¼ inches from it. Also draw two parallel lines, the first 1⅛ inches, and the second 1¼ inches from the first, parallel to the back edge of the sheet. In the same way, draw two parallel lines along the front edge and also two lines along the lower edge at their proper distance from the edge of the sheet.

Referring to the left hand side of Fig. 19, the second row of rivets will have 22 equal spaces and the first row 23. In the same way at the right hand side of the sheet, the second row will have 28 spaces and the first 29. Some of the rivets in the water space frame are equally spaced, and the remaining rivets will be shifted slightly from the equal spaces, to suit the various figures here shown. Care must be taken in laying out the rivets in the lower edge, as they must match a similar construction upon the water space frame.

If a templet is made, as it sometimes is, these rivets would be laid off on the templet. After the holes were drilled in it, they would be marked off from the templet, both on the sheet and on the water space frame. If the angle is correct, the holes will match up, when the sheet is put in place. The stay bolts will now be laid off. On the front of the sheet lay off spaces corresponding to the figures which have already been laid down full size on each view. In the same way at the front part of the sheet, the distance corresponding to the figures here given, would be laid off. With a straight edge draw a line through the points thus found, from one end of the sheet to the other. These lines will not be parallel to each other, but will converge, being further apart in front. Draw a line D–D, 22¼ inches in front of the vertical portion of the back edge. This line will be drawn at right angles to the center line.

The stay bolts will be laid off to the left of this line to suit the figures. The remaining lines from D–D to the front row, which is 4½ inches from the front edge, will be equally spaced. All these lines will be drawn at right angles to the center line. The rivets above the line D–D and those three spaces to the right, will be equally spaced to suit the inclination of the outer edge. All the stay bolts which are marked with a center and a circle around it will be flexible. The few remaining rivets can readily be laid off to suit.

Four stay rods are required in the front head. They will extend forward and be attached to the sheet. They will be spaced at the intersection of the lines joining the center of the stay bolts as nearly as the spacing in the foot of the stay rod will admit. This completes the work on this sheet.

Outside Throat Sheet.

The throat sheet shown on Plate 3 is a rather difficult sheet to flange and fit to the boiler and also rather hard to lay out. For this reason, take this sheet and follow it around to determine the various relations that go together to make up this very important sheet in the boiler. Fig. 20 shows a section through the center of this sheet, and the dimensions here given correspond with those given in Fig. 21. This latter figure represents the flat sheet as it will appear before going to be flanged.

Layout of outside throat sheet.

The center line C–C of this sheet is now drawn and a line laid off at the top of sheet with a half-inch allowance for variations in flanging. Then a line is drawn at right angles to C–C at this point.

The intersection of these two lines will be the center of the boiler, and from this center strike the inside radius R of the sheet. The distance L along the neutral line of the sheet in Fig. 20 is measured off along the center line C—C and a line is drawn from the lower extremity of the sheet at right angles to C—C. When this sheet is flanged the first operation is to bend as shown in Fig. 20 along the neutral line L. While being held in this position by the auxiliary pistons of the press, the outer flange is bent up and forms the part that fits the side sheets.

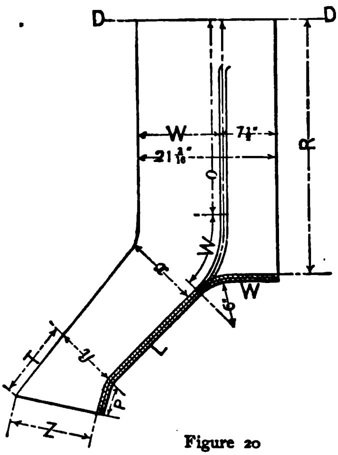


Figure 20

Section through outside throat sheet.

The next operation can not be done on the press but must be flanged by hand. This consists in turning the inner portion of the sheet in the opposite direction to the part just described. The upper portion of this sheet, corresponding to the line D–D, will thus be a straight line, the front portion having been turned forward and the back portion backward.

The total length of the flange at this point is $21^3/_{16}$ inches. The inside portion of the flange will extend in towards the center of the sheet $7^3/_{16}$ inches. This distance is laid off on the plate as indicated, giving the limit of the sheet along the top portion. The distance O is the same in both figures, as is the distance M. The distance O is laid down from the top center line and a circle is struck through this point O and the two points determined by the figure, giving $7^3/_{10}$ inches.

This represents the portion of that part of the flange which is turned forward. The radius at the point W is 8½ inches and on the sheet this distance W, the radius, the width of the sheet and also its thickness are laid down to determine the length of the neutral line. It will be noticed that the radius described from the extremity of L falls inside of the line of the sheet. Therefore we will not need to continue any further with this construction.

The radius at the point X is also 8½ inches and the figures at this point will be used in making the construction to determine the neutral line B. The point thus determined gives the least width of the sheet. The radius at y and z is 6 inches and the construction is made to determine the length of the neutral line C and D. These distances are laid off to suit and thus the right and left hand sides of the sheet are determined.

One thing should be mentioned here in reference to the lower corner of this sheet. The angle between the water space frame and the throat sheet, immediately in front, is 90 degrees, which would seem to indicate that the development of the lower portion of the sheet would be a straight line. It would be if, during the process of flanging, the portion of the sheet marked T would be stretched. This is not the case however, and the length T before and after flanging will be the same. For this reason the distance P is laid off in Fig. 21 to correspond

Fire box throat sheet.

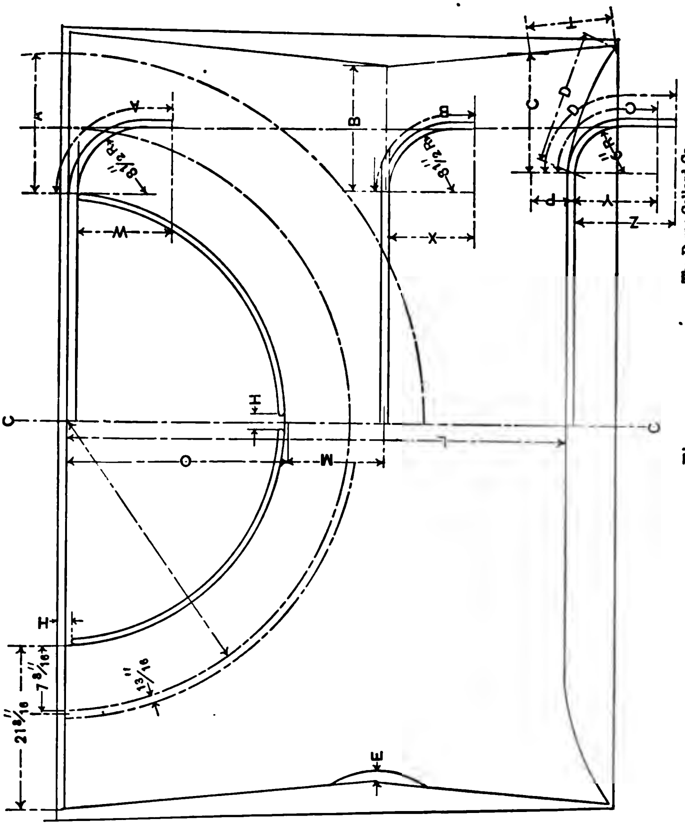


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Figure 21

Layout of outside throat sheet of boiler shown in Plate 8.

to the length of the neutral line at P in Fig. 20, and the length T is laid off from the point thus determined. This brings a point on the corner of the sheet as indicated.

There will be some stretching action somewhere along the curved line here shown and it is found that a radius thrown in at this point will come better when flanged than it would if a straight line was worked to. For this reason a radius should be struck at this place as shown. The flange of this sheet is very long at X and on account of the upsetting action of the sheet at this point, the metal will flow and be drawn by the action of the press, so that there will be a considerable bunching up of the sheet at this point. On this account a semi-circular piece is cut out as shown at E and for a sheet of this size E would be 1½ inches. No holes will be put in this sheet before flanging, although it is frequently laid out and all the holes counter punched. After flanging, the sheet is taken to the laying out table and measured up. Wherever the sheet has drawn, the old center is hammered shut and a new center put in to the correct figure. The three bridges marked H in Fig. 21 must be allowed to remain, together with the central portion of the sheet, in order to hold the sheet together during flanging.

Fire Box Throat Sheet.

Fig. 22 shows the fire box throat sheet of a Wooten boiler as seen on Plate 2. Draw the center line C–C in the center of the sheet and then from the figures on the drawing locate the center line D–D. The center of the boiler will be at the intersection of these two lines. The lower portion at the water space frame will be 49⅞

Fire box throat sheet.

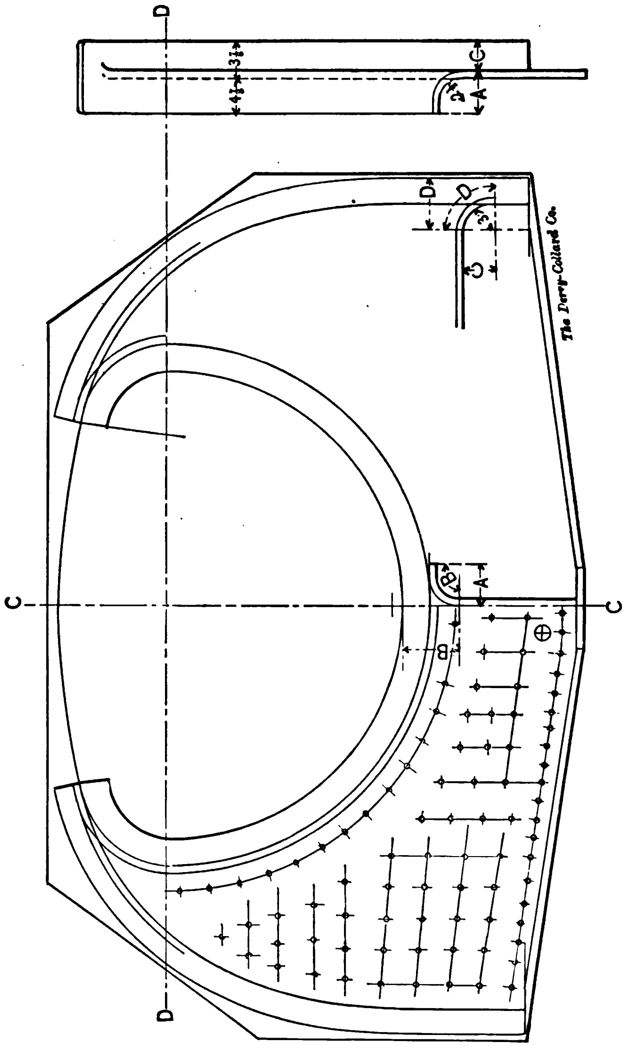

Figure 22

Layout of fire box throat sheet of Wooten boiler shown in Plate 2.

inches from the center line D–D. There will be a flat portion at the bottom, and then a slope line for a distance of 6 inches, then again a flat portion at the top. These will be laid off to suit the figures on the drawing. A sectional view of this throat sheet is shown on the right hand side of Fig. 22. The height of the flange marked A, together with the radius and the thickness of the sheet, is laid down along the center line C–C. The length of the neutral line B will be obtained by the measuring wheel and laid off along the center line as shown. This represents the developed position of the lower portion of the flange at the bottom center. The 2½-inch radius will extend all the way around the throat sheet until it disappears in the flat portion of the flange at the top of the sheet. The inside flange will have the same width all the way round. The inside limit lines can now be drawn from their respective centers. The height of the flange C which extends back along the side sheet, and the radius corresponding to the water space frame at this point, will be laid off and the length of the neutral line be determined. This gives the extent of the flange on the outside and this radius will be maintained until it disappears into the flat portion of the sheet. The flange will have the same width throughout and will be drawn from the respective centers.

As the top portion of this sheet, like the one shown in Fig. 20, is to be flanged along the straight line, this line will, in the development, be radial, pointing toward the center from which the lines of the flange have been described. One single row of rivets in the water space frame will now be laid off at the distance corresponding to the detail card, which shows the rivets in the frame. Twenty equal spaces are required on each side of the center. The first through rivets are 5¾ inches from the outside of the water space frame.

The stay bolts will now be laid off as shown on the drawing. Next the line of throat stays will be laid off and the distances spaced to suit. A 1½ pipe tap is required right and left and will be laid off to agree with the figures. All the holes shown in this sheet can be punched or drilled before flanging as the flanged portion is very narrow and there would, for this reason, be scarcely any drawing of the sheet.

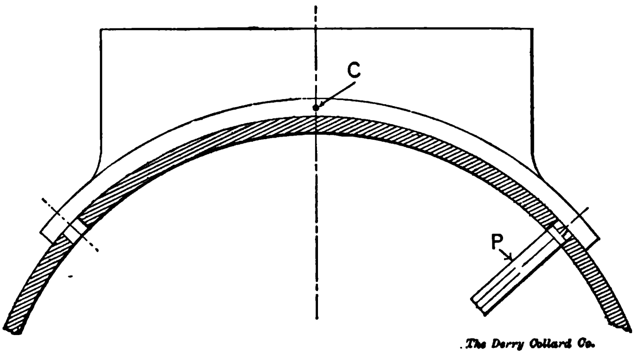

Figure 23

Method of laying out holes in dome flange.

General Remarks in Laying Out.

In boiler work as in all other work there are no two shops which do the same thing in exactly the same way. One method may be very cheap and expedient in one shop, yet the same method elsewhere, with the conditions surrounding the other place, may be difficult and expensive. In some cases the holes in the dome flange, Fig. 23, will be marked off from the inside of the sheet with a punch P. The center punch mark shown at C is put on the sheet when it is flanged. This is set with a top center line on the boiler, and the dome flange is held to the boiler by several bolts, while all the holes are punched from the inside. The sheet is then drilled, put together and reamed. Another way of doing this work is to have a sheet iron gage in which the holes are all punched and

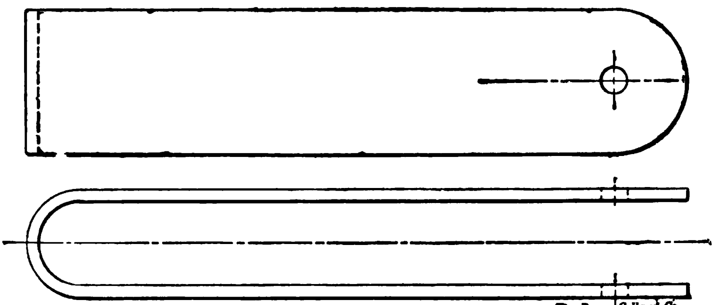

Figure 24

A "back marker."

which can be laid along the outside of the dome flange and the holes laid off from the sheet. The dome is then held in place by a few bolts and the boiler is swung under a radial drill and the holes drilled through the flange and sheet.

Fig. 24 shows what is termed a back marker and may have many different shapes. The idea is that when any portion of a boiler is marked off from another sheet by a center punch from the inside, and the drilling must be done from the outside, this back marker straddles the sheet and is made to coincide with the punch mark on one side while the holes are marked off in the other side. The holes of course must come directly opposite.

The dome cap shown in Fig. 25 is frequently laid

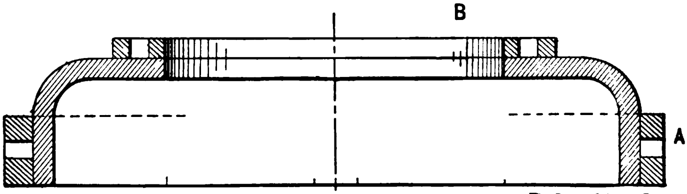

Figure 25

Dome cap laid off in gages.

off by gages as shown at A and B. Where domes can be kept to a standard size, as they frequently are, a gage

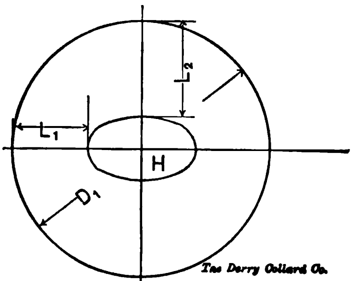

Figure 26

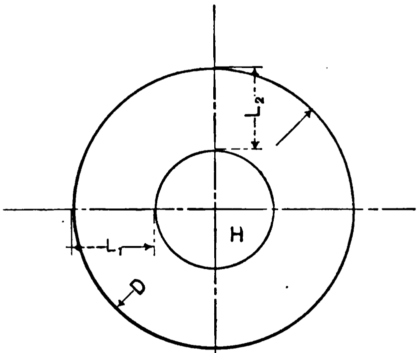

Figure 27

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Dome flanging.

saves a great deal of time in laying off the work. The gage is held in place and the holes punched where they belong. A dome flange like that shown in Fig. 23 will have an elliptical opening in the sheet before flanging, as in Fig. 26. Here D will represent the neutral diameter of the sheet and L_1 and L_2 will be the neutral line of the sheet along the flange on the center line of the boiler and on the side center respectively. A comparison of such a dome with the one that is sloped down to the radius of the boiler will be seen by referring to Fig. 27. Here L_1 and L_2 are equal and H is a circular hole. It is believed that the number of sheets taken up in detail will enable anyone with a fair knowledge of the subject to lay out any work that will be met in boilers of any type.

Flanging and Forging.

Flanging.

A number of sheets have been shown which require to be flanged immediately after having been laid out. Other sheets require punching and shearing before being flanged. Fig. 28 shows the corner of a sheet such as would be found at the corner of the water space frame or at the dome cap, and in flanging it should be remembered that the radius R should be kept as large as possible. This is especially true where holes are required around the corner of the sheet. When the holes are punched, which is done when the radius is large,

Flanging.

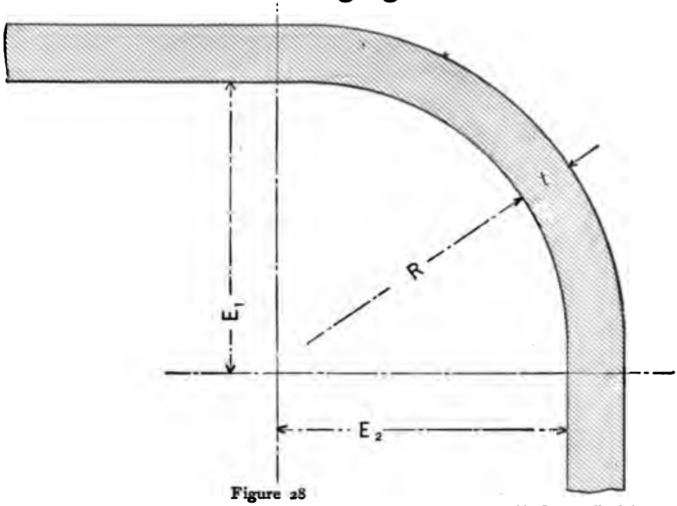
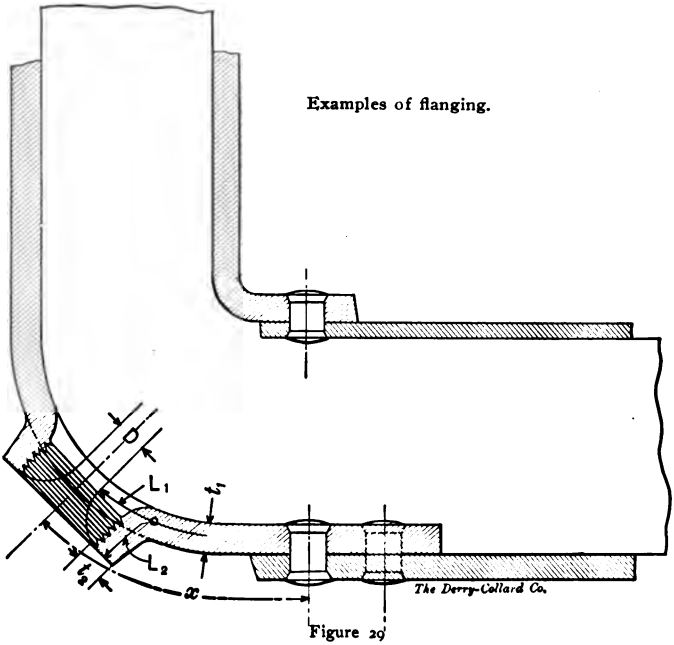


Figure 28

The Derry-Collard Co.

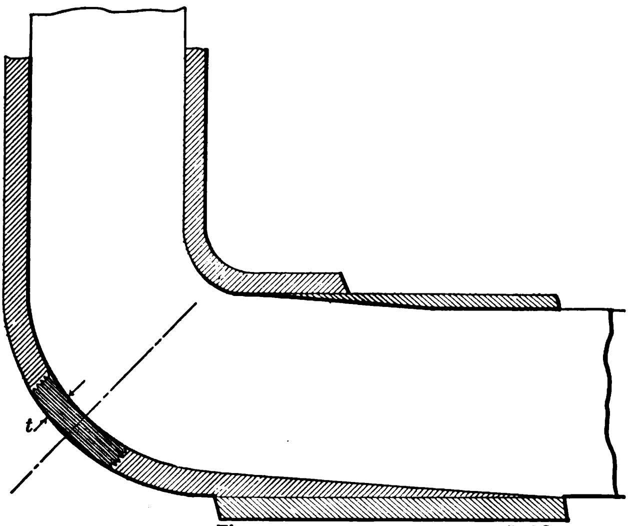


Examples of flanging.

Figure 29

the sheet is apt to crack during the operation, especially if the metal has been badly crushed in flanging.

The thickness of the sheet, of course, has a great



Flange or large radius.

influence upon the radius R and when the sheet is thick, R should be made large.

Fig. 29 shows the cleaning plug in the corner of the water space. The metal is flanged so as to give a greater length of threads to the plug than could be obtained by going directly through the sheet as in Fig. 30. If the radius around the corner is very large and if the sheet is thick, the construction shown in Fig. 30 is quite satisfactory, but when the radius is small and the sheet is thin the flanging process in Fig. 29 is frequently resorted to. In the first place a dimension is usually given

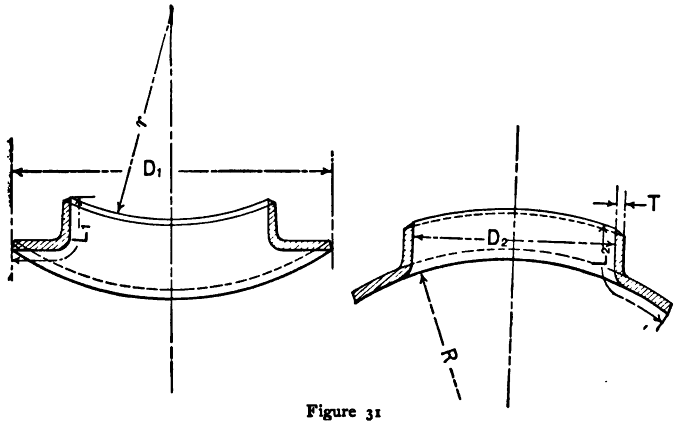


Figure 31

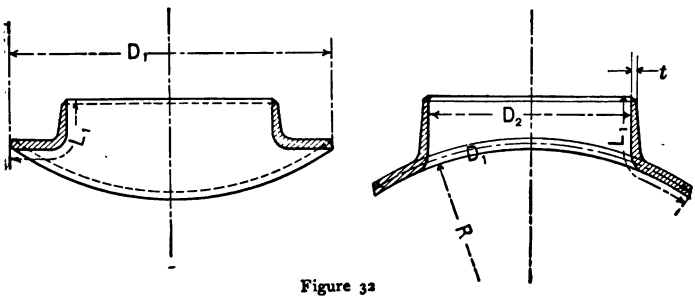


Figure 32

Dome flanges.

at X for the location of the center of the hole along the neutral line of the sheet. The hole is laid off to this figure, at the proper distance from the bottom, and a ½-inch or a ⅝-inch hole put in at this point. After the main sheet has been flanged, the corner around this hole is heated and a drift is driven through which drags the metal with it, carrying it out as shown in this figure. Sometimes the metal in being drawn out becomes very thin at t_2 and in this case the metal is driven back and upset to some extent, so as to thicken it up to the proper amount. L_1 and L_2 will have the same length before and after flanging, D being the diameter of the hole which is put into the sheet at the beginning of the operation.

A dome flange of the style known as being curved down to the radius of the boiler, is shown in Fig. 31. The advantage sought for in this style of dome is to keep the thickness of the metal at T as great as possible. It must be remembered that the length along the periphery of the hole in the sheet before flanging, is increased to the length of the neutral line of the sheet at T, and of course the thickness of the metal must vary in the inverse proportion. That is, it stretches and certainly will be thinner.

Fig. 32 shows the style of dome which does not have this feature, but which is a very convenient dome to fit up. The hole in this sheet before flanging is elliptical and there is a great deal of this stretching action necessary in order to bring the metal from the small hole in the center of the sheet to a distance equal to the diameter D_2 in the figure. The sheet is circular before flanging, of a diameter D_1, and the distance L_1 is readily seen to be very much less than the distance L_2. These two distances, properly measured from the circumference of the sheet, determine the size of the whole before flanging. L_1 and L_2 in Fig. 31 are equal, which of course means that the hole in the sheet before flanging is a circle determined by this distance. The radius is very nearly equal to R, but is spoken of as being equal to it. Each one of these sheets should be machined perfectly smooth both on the inside and the outside before flanging.

If the contour of the hole were punched and nothing else done to it, the metal would draw away from the holes and the metal would be much thinner than it would be at the top. This same thing should be remembered in the flanging of any sheet. If the burrs left by the punch or drill cannot be machined off, they should be chipped away by hand or by a pneumatic chipper.

The smoke stack base, when made of wrought iron or steel, is very thin and usually shaped somewhat as shown in Fig. 33. The sheet is rectangular, of a size equal to A and B. This sheet is first bent to the radius of the boiler R and, while being held in this position by the dies, a ram is pushed through the central portion, opening it to the diameter D of the smoke stack, the unnecessary metal being removed by a horizontal punch. Another place where a very thin sheet is used is the dome cover or casing, which is about ⅛ inch thick.

In a great many places the spherical top of the dome cover is made up of sections which have been flanged by hand, being gradually hammered out to the shape and the various sections cut and fitted together. This operation is an exceedingly expensive one. A great many attempts at flanging this sheet have failed, and caused a great many people to give up the idea. It can be done, however, and is the practice at several places. The plan is shown in Figs. 34 and 35. To begin with, a very fine grade of charcoal iron is best for this and instead of trying to flange this sheet at one operation, it must be

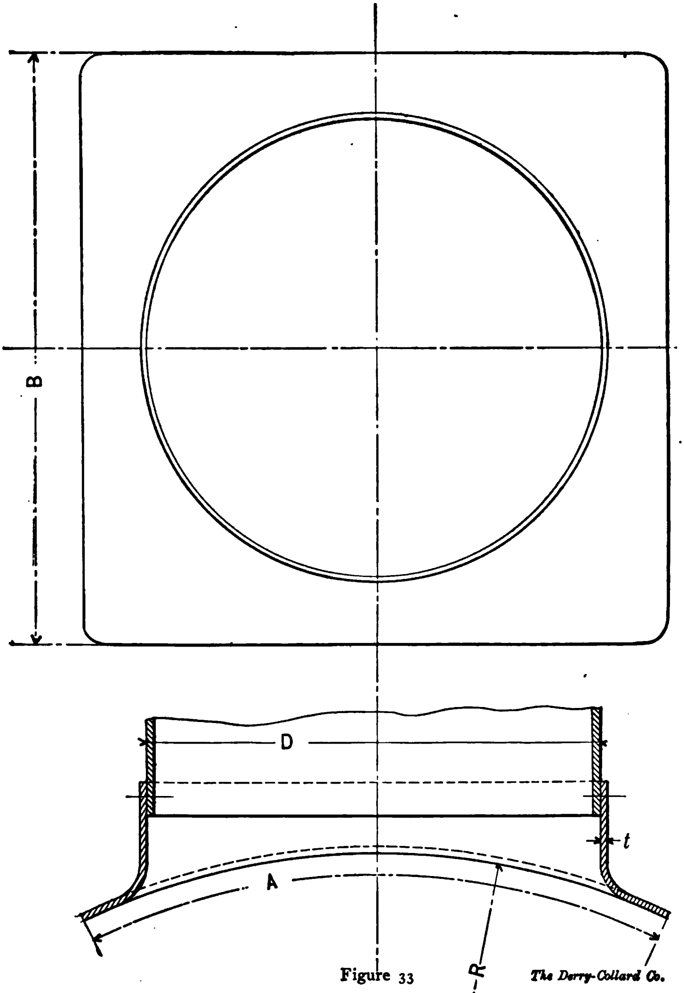


Figure 33

Smoke stack base.

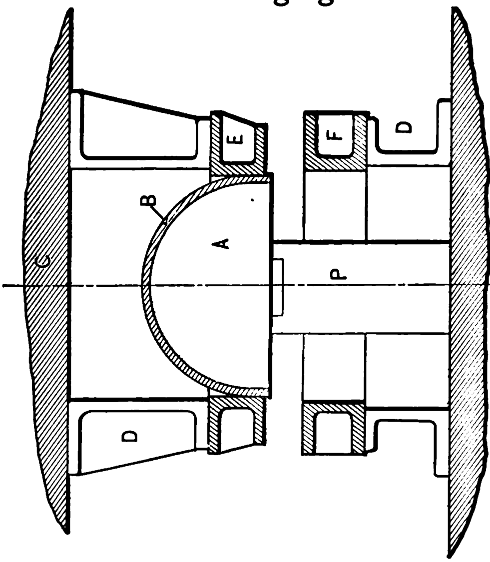


Figure 35

The Dorr Collard Co.

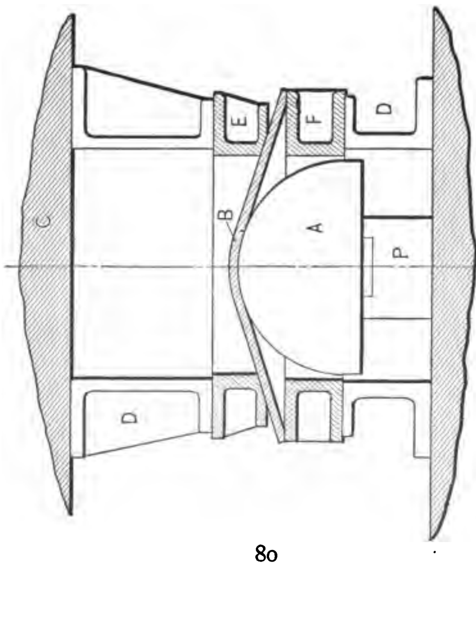


Figure 34

Flanging of spherical top of a dome cover.

carried through several, and of course, through as many heats. The knack of this process is to keep the sheet from buckling and this is done by bringing the dies E and F at just such a position that when the ram is brought up the sheet will assume the position shown in Fig. 34 and thus any tendency to buckle is prevented. The first operation upon the sheet would bend it about as shown in the figure. The ram is lowered as well as the main table. The sheet is removed and again heated. It is then put back into the machine and by careful manipulation of the press the sheet is bent a little further. Four or five of such operations will bring the sheet in a perfectly spherical shape as seen at B in Fig. 35. The die A is pushed through E and the sheet removed from the top.

The rear end of the boiler shown in Plate 3 shows a very large sheet, which would be flanged as shown in Fig. 36. C is the cap of the hydraulic press, which is adjusted to suit the height of the die; E is the upper die which is supported by standards D from the cap; F is the lower die, supported on the jacks G; H is the matrix, supported by columns D from the main table; P is the internal piston or ram and A is the fire door die.

We will follow the sheet from the furnace to the machine. The very ingenious arrangements shown in Fig. 37 are convenient for bringing the sheet from the furnace to the press. It consists of a bar with an alligator jaw at the one end and having the top portion of this jaw forked so as to admit an eccentric saw tooth disk R. An arm H inclined towards the operator in order that its weight may always keep the disk engaged, is provided with a hand chain by which the disk can be tightened up. A twist chain is attached to an eye in the

Flanging.

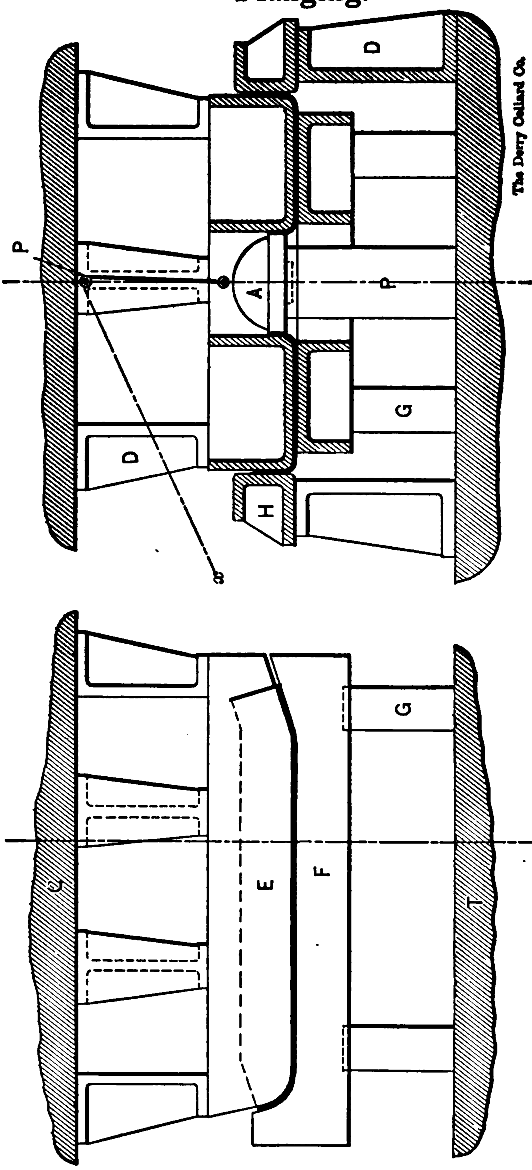


Figure 36

Flanging the rear end of boiler shown in Plate 8.

other end of the bar, and a four or a six to one air or hydraulic hoist is coupled to this chain. By this means the sheet is drawn out into place.

The matrix will have pins or blocks bolted on so as to line up the sheet, which must now be barred and pushed into place by pinch bars or bars similar to Figs. 38 and 39. Having lined up the sheet quickly upon the matrix, the auxiliary jacks are brought up, which carry the sheet and clamp it between the dies E and F. While being held rigidly in this position, the main table and the internal piston are brought up together. The matrix thus flanges the outer portion while the internal piston with its die A is forced through the fire door opening. The piston P forces the die A entirely through and then with a chain or rope passing on a pulley P holds the die in this position.

The matrix is now returned, the four auxiliary cylinders are lowered, the main piston is lowered and the sheet is removed. The internal piston is now raised to receive A and is then returned to its original position.

The gusset sheet shown in Plate 2 will not be exactly as shown on the boiler after being welded, for the reason that when the sheet C comes from the mill the elements will be straight lines and as the sheet must join cylindrical sheets, front and back, it must be flanged so that the sheet will be cylindrical at these points. This is done by heating about one-third of the circumference of one end in a fire and then flanging this portion by hand so as to fit the other sheets. The drop of the gusset H shown in Fig. 40 being known, a straight edge is laid across the top of the sheet as shown so as to obtain this amount.

When we have a sheet like the upper part of the

Flanging.

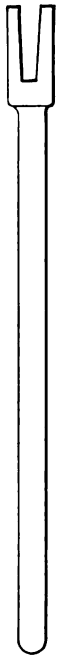


Figure 38

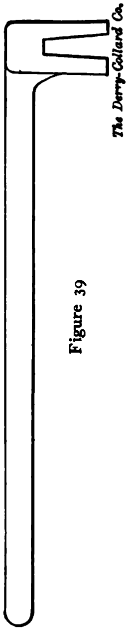


Figure 39

Pinch bars for flanging.

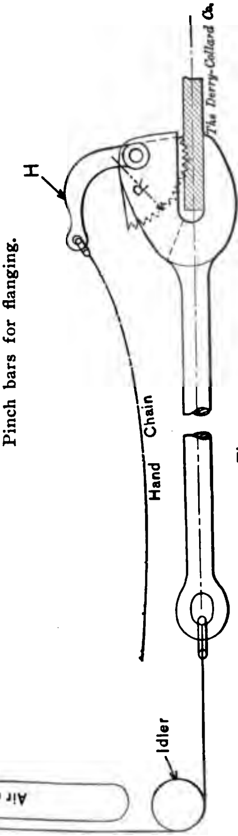


Figure 37

Device for handling hot sheets for flanging.

gusset in Plate 3, the back portion is flanged first. Fig. 41 shows the cross section as it would appear in the dies. Fig. 42 shows the shape of this sheet after it comes from the press. It will be noticed in this sheet that the flanged portion does not extend all around and for this reason the upper and lower dies are made to slide upon each

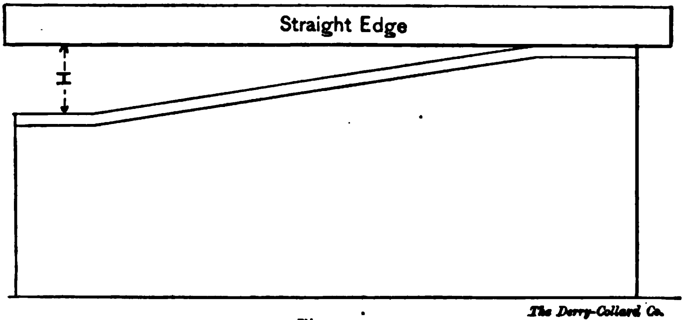


Figure 40

Straight edge for gusset sheets.

other at X, while they have clearance for the thickness of the sheet elsewhere. Fig. 42 shows bridges at B, the metal having been removed by a cutting punch as shown at C. These bridges must be allowed to remain in order to hold the sheet firmly together while the outer portion is being flanged.

The die B, in Fig. 41, is supported from the cap of the press, while the die A is carried upon the four auxiliary cylinders and clamps the sheet. The matrix E is supported from the main table by the columns D.

The process of flanging the dome cap in Plate 2 will next be considered. The flanged sheet is shown at F

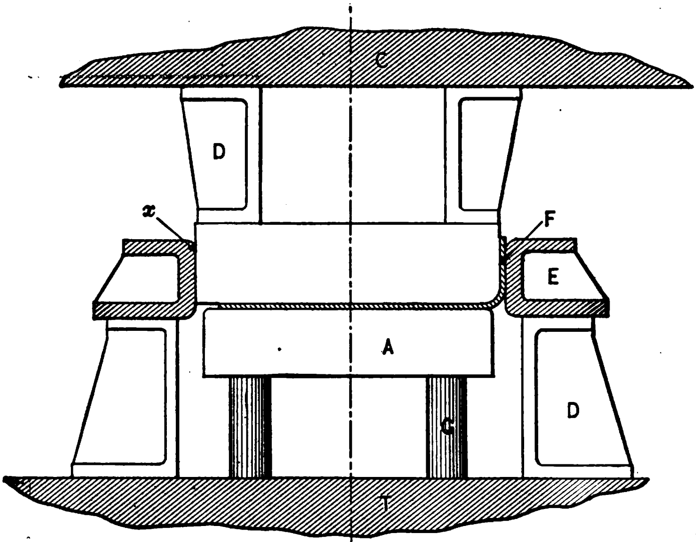


Figure 41

Dies for flanging gusset sheets.

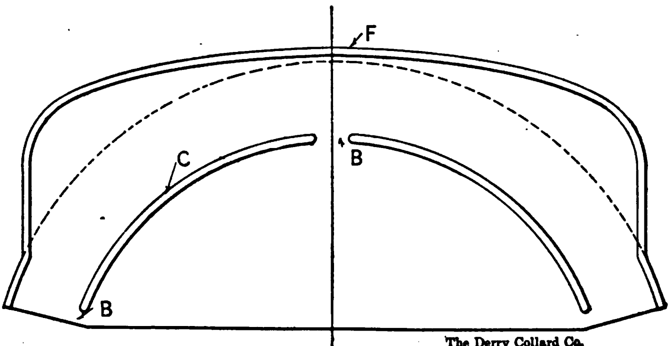


Figure 42

Gusset sheet after coming from die press.

in Fig. 43. It is brought from the furnace and centered upon the matrix by pins S. The clamping piston P is then brought up, clamping the plate between A and B. The next operation is to turn the water through the main valve, thus bringing the matrix E up against the sheet. The flange is thus carried up and shaped in the way in-

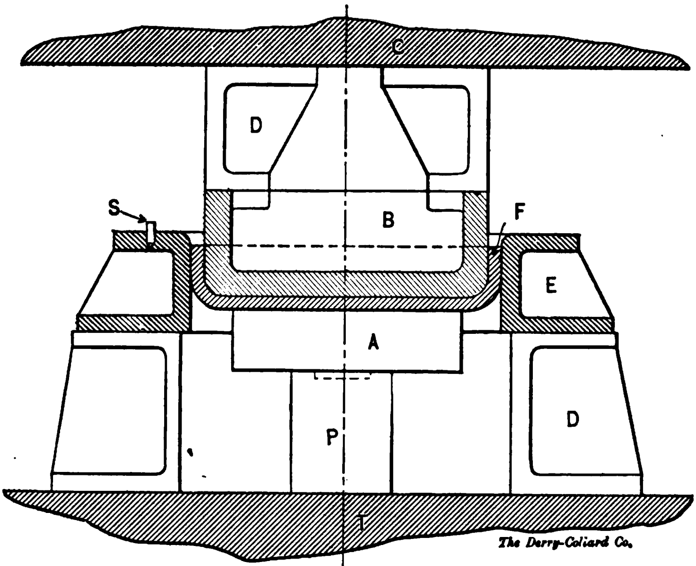


Figure 43

Flanging dome cap.

dicated. The dome flange or dome base is usually made of 1⅛ or 1¼-inch steel plate. The one shown on Plate 1 is seen in section as it would appear when in the dies in Fig. 44.

The first operation upon this sheet is to clamp it be-

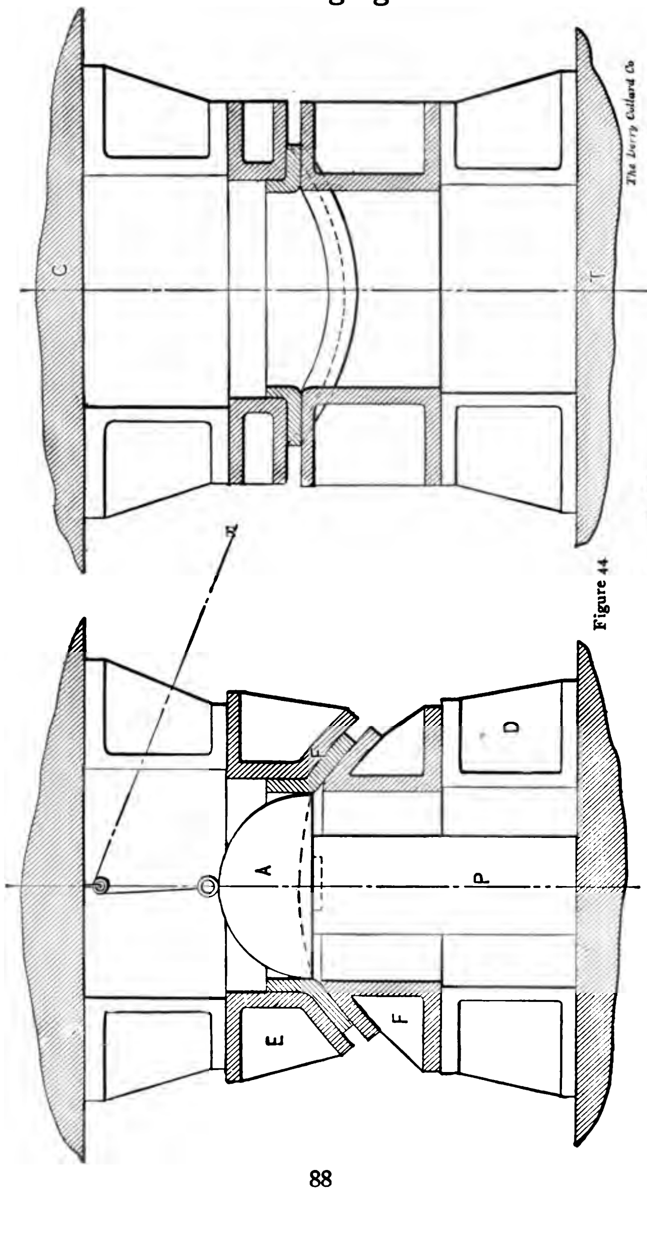


Figure 44

Flanging dome cap shown in Plate 1.

tween the dies E and F and while being rigidly held by the main table, the clamping piston P and the dies A are brought up. The die A forces the metal to the side as the piston pushes it entirely through the flanged sheet. A rope or chain X now supports the die A while the piston P is returned.

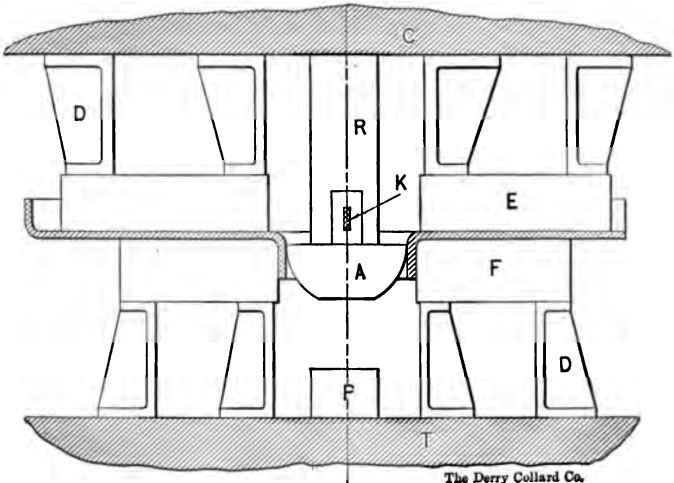


Figure 45

Flanging fire doors of Wooten boilers.

While the dome flange is thus held between the dies, a center punch mark is made on the top of the center line of the flange front and back, and the flange is set to this mark while being machined, and while being fitted to the boiler.

The rear end of the Wooten boiler in the Plate I

Flanging.

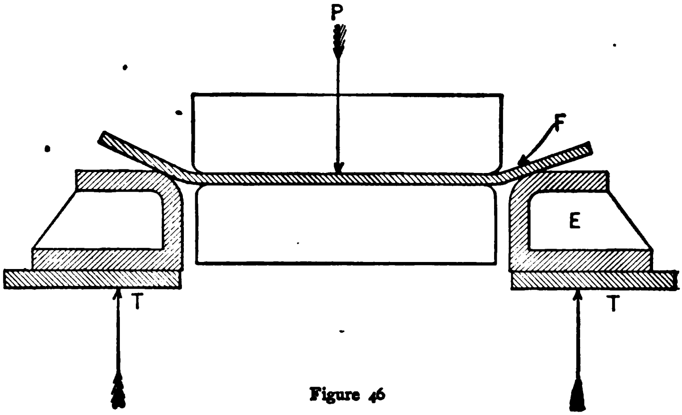


Figure 46

Heavy flanging.

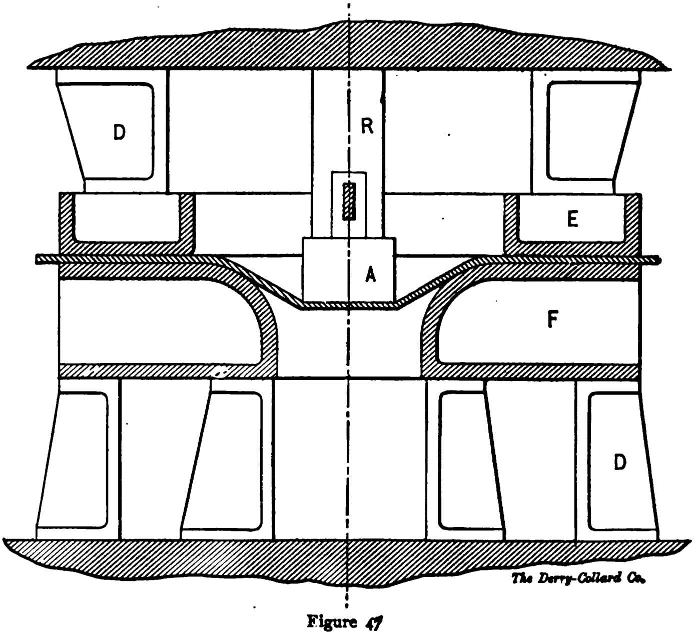


Figure 47

Flanging fire door shown in Plate 8.

shows the back head flanged in opposite directions. The outer portion of the flange is the first operation, then the sheet is reheated and placed in the dies as shown in Fig. 45, when the fire doors are flanged one at a time by the die A. The press here shown has a top cylinder and

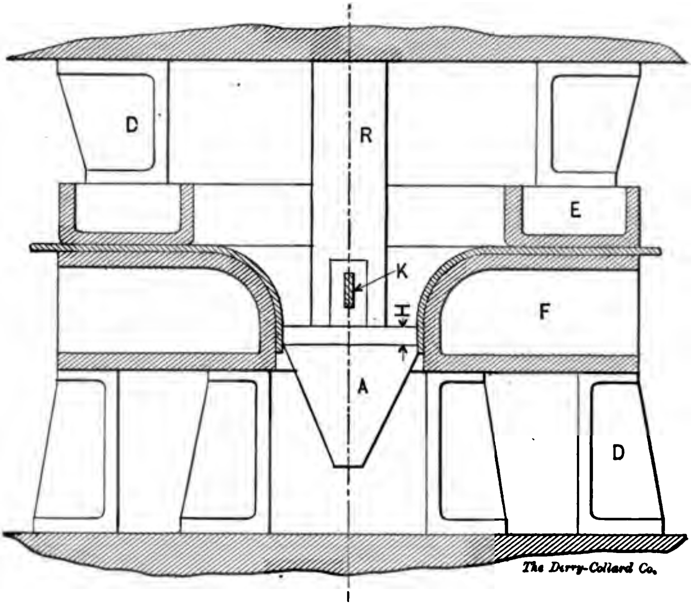


Figure 48.

Flanging fire door shown in Plate 3.

this cylinder is provided with an adjustment along the line radially from the center. The operation would be just the reverse of this, in case the machine we were using was not provided with a top cylinder. In this case it would be flanged by the clamping piston referred to in

Fig. 45, where the piston R forces the die completely through the fire door. The die A is now received by the piston P. The key K is withdrawn and the piston R returns to place. The table is lowered and the sheet removed.

In flanging very heavy sheets and especially when the flange is deep as is the case in the throat sheet of Plate 3, an exceedingly severe strain is brought upon the dies. There is something of the action of a wedge upon these dies just before the flange is nearly complete. As the metal is very soft at this heat, there will not be near as much friction as there would be if the metal were cold, consequently the wedging action is more severe. The dies often break in this kind of work.

Fig. 46 shows a cast iron die at E, flanging the sheet

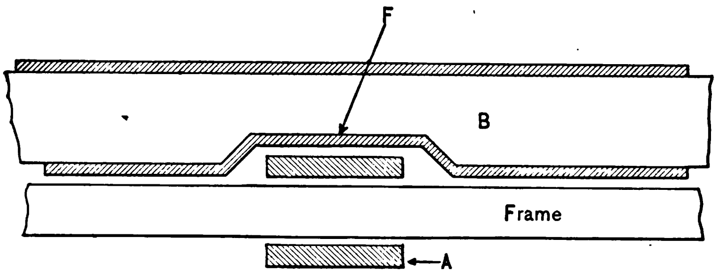


Figure 49

Flanging spaces between boiler and frame.

F. Upon this die there is acting a force P, which tends first, to bend the dies downward, secondly, when the flange is nearly finished, to press the dies outward. A reenforcing plate of wrought iron bolted to the die E adds wonderfully to its strength. It should always be placed on the tension side of the die and so strengthen the die in both directions.

When the back end of the boiler is shaped like Plate 3, frequently a long flange is required for the fire door. This is obtained in the manner shown in Figs. 47 and 48.

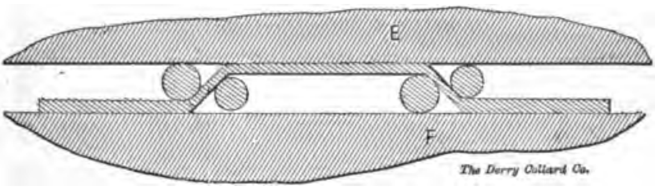


Figure 50

Cross section showing flanging of Fig. 49.

The first of these two figures represents the back fire box sheet clamped between the dies E and F. The first operation is to bend the sheet with the die A, thus stretching the metal from the beginning of the fillet, until a position is arrived at, gaged by experience, somewhat as shown in the figure. The sheet is then removed and a 3 or 4-inch hole is bored through the center, depending upon the size of the door. Then it is reheated, centered upon the dies F and clamped to E. A conical shaped die A is now forced through the opening and flanges the sheet as seen in this figure. The die A is pushed through and the key K removed. A flat portion of about 1½ inches is allowed upon the die at H.

In Fig. 49 is seen quite a common construction where the boiler fits very snugly between the frames and where it is desired to get a spring staple, or some other construction between the boiler and the frame. The mud ring is notched out at T and the sheet is flanged to fit it. Fig. 50 represents a cross-section through this sheet and the dies used in bending it. The dies used for this pur-

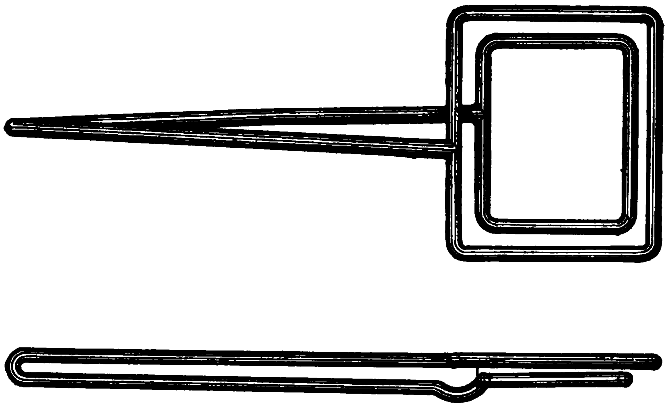


Figure 51
Dies for flanging in Fig. 49.

pose are very simple and cheap. They are indicated in Fig. 51. They are made out of round iron of a diameter equal to the set of the flange and bent so as to give the required size and angle to the sheet. A mark is placed on the die. Having located the die to suit this mark and laterally to suit the lines laid out on the sheet, the dies of the machine E and F, Fig. 50, are brought together and the sheet is flanged.

In Plate 2 will be seen a crown bar T iron, which is bent to suit the curvature of the crown sheet and also one above it to suit the curvature of the sheet. Referring to Fig. 52, D_1 and D_2 are cast iron dies, R being the required radius. The iron is heated, placed between the dies and forced together by the hydraulic pressure. These dies are rough castings except at F where they are planed.

In conclusion a few remarks on the size of the dies may be of value in order to turn out the finished product to the correct dimensions. From a large number of experiments it has been found that the contraction of sheets, in cooling, from the usual red heat of flanging, is three-

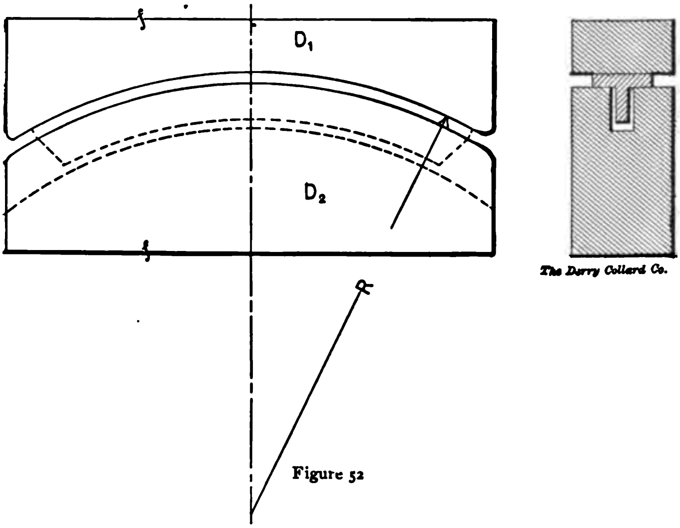


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Figure 52

Dies for curving crown bar T iron.

quarters (¾) of an inch in seventy-eight (78) inches, which is very nearly one one-hundredth (.01) of an inch per inch. This effect, of course, extends in every direction and all the dies should be made larger than the figures on the drawing in order to accommodate this amount.

Forging.

A great many water space frames or mud rings are made of forged iron. Fig. 53 shows one of these corners. They are usually made in one of two ways. First, four pieces of the proper length are forged, upset on their ends and welded across the corner at A. Or, secondly, four corner pieces are forged, and then pieces welded on to these to give the proper length and width of the frame. The weld coming at B, sufficient metal is allowed for machining the frame inside and outside. In certain arrangements of the boiler the throttle lever rod comes through the dome flange at E, Fig. 54. In this case a regular dome flange is taken and a piece P welded upon it, of sufficient size to shape to the dimensions required.

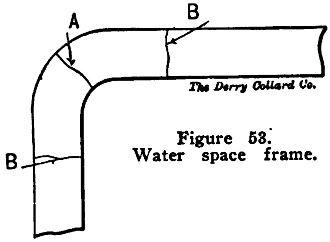


Figure 53.
Water space frame.

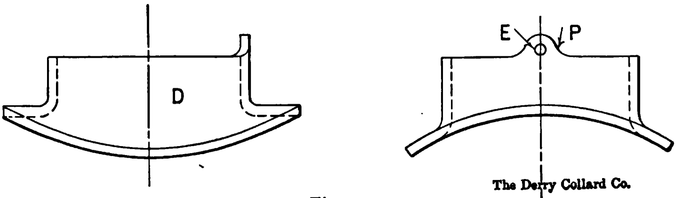
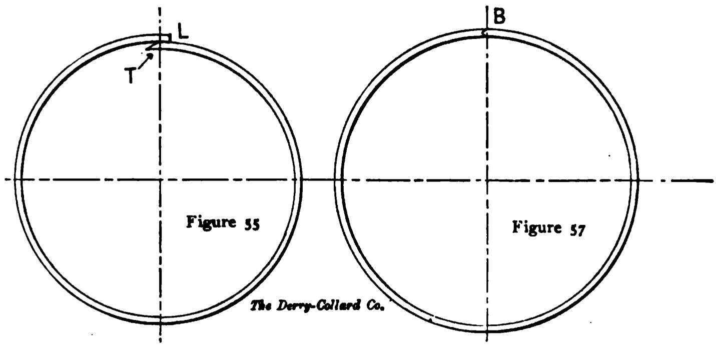


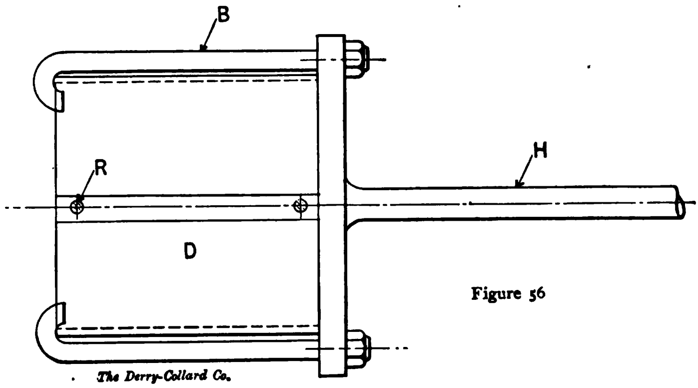
Figure 54

Lug for throttle lever rod forged on to dome flanges.

The dome sheet as seen on Plate I is frequently welded along the vertical seam. This is done in several ways, the most common of which is shown in Fig. 55. In this case a seam is allowed and one edge of the sheet

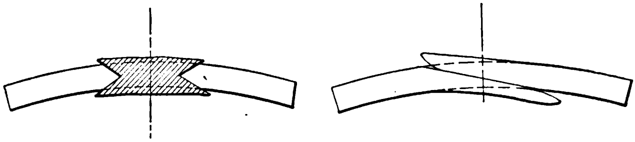


Welding of dome sheet.



Device for holding dome sheet for welding.

is scarfed. A small bolt is placed in each end of the seam to hold it in position as shown at R, Fig. 56. A



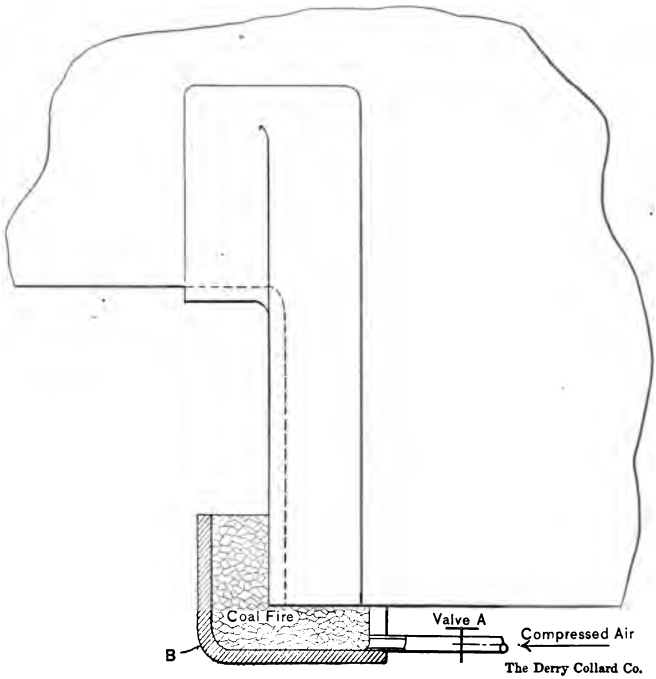


Figure 60.
Method of heating for forging.

common arrangement for holding this sheet during the operation of heating and welding is also shown in this figure. It consists of a T shaped handle H, and two

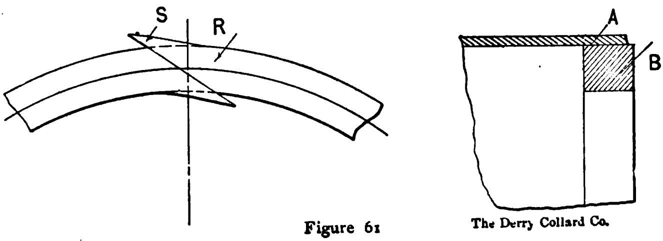


Figure 61

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Smoke box rings.

hooked bolts P. The whole thing is readily slipped upon a special long anvil while the seam is welded. This operation is done by hand. Fig. 57 shows another way of forging this sheet, which is rather more difficult to do.

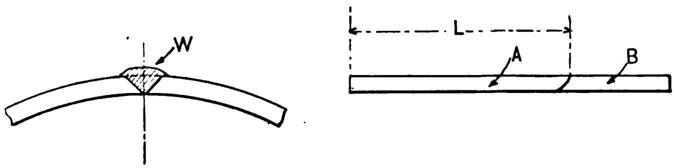

Figure 62

Welding the seams of the first course.

Fig. 58 shows a wrought iron piece let into the seam and is claimed by some to make a better weld, while Fig. 59 shows the sheet double scarfed at the seam. After the boiler is partly assembled there is a considerable amount of "sleight of hand" work which must be performed upon the sheet so as to bring it up into place. Sometimes this can be done cold but as it is a bad thing to do much hammering upon a cold sheet, a charcoal fire is built around the place and the sheet is thus heated to a cherry red.

In Fig. 60 is shown a much more rapid method of heating than can be obtained by either charcoal or wood. B is a cast iron box of any shape to suit the work. A small amount of coal for the work is placed in it. Compressed air is led to the box through a valve A and thus a little forge fire is applied directly to the part which is required to be heated. Oil or gas can also be used if they are obtainable.

In all the boilers shown in the back of this book, smoke box rings, as B, Fig. 61, are used.

A bar of iron of the length equal to the neutral diameter of the ring, *plus one and one-half times the thickness of the ring, plus one-fourth of an inch,* is bent into a circle. The ends are scarfed as at S and the seams welded. Formerly these rings were machined both at A and B, but the finish is being abandoned at A and the ring forged, so that the outside diameter will just fit the smoke box sheet. The outside diameter of the ring should be made to give the same run of the measuring wheel as the inside diameter of the smoke box sheet.

One of the largest locomotive builders in this country welds the seams of the first course for a distance of 10 inches on each end. The method is shown in Fig. 62. The end of the plate is planed square at B and beveled off to an angle of 45 degrees at A. This extends for a distance of about 10 inches. A wrought iron piece W is then welded into the gap at each end of the sheet.

Punching.

Operations requiring the punch constitute such a large portion in the construction of boilers that it seems best to devote this space entirely to it. You cannot mar a plate in any way without affecting its strength, and when a hole is punched into a plate the plate is reduced

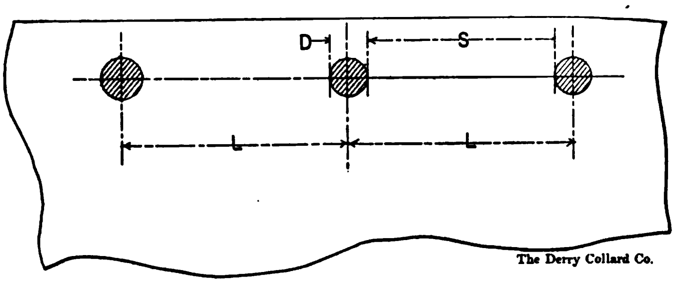

Figure 63.

Punched work.

in strength in the section containing the hole. Fig. 63 shows a portion of a plate with holes punched along its edge. These holes decrease the strength of the plate along the center line of the holes in the following proportion:

Punches for boiler work.

Let L = the pitch of the holes = 6.5 inches
Let D = the diameter of the holes = 1 inch
Let S = the distance bet. the holes = 5.5 inches
Let E = the efficiency of the plate

$$\text{then } E = \frac{L - D}{L} = \frac{6.5 - 1}{6.5} = \frac{5.5}{6.5} = 84.6 \text{ per cent.}$$

This is about the percentage of strength of a plate along the third line of rivets of a triple riveted joint. In addition to the decrease of strength of the sheet, there

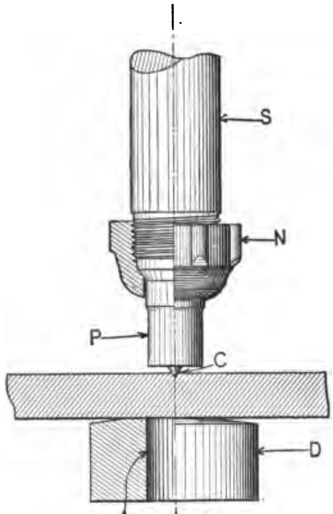

Figure 64
A common punch.

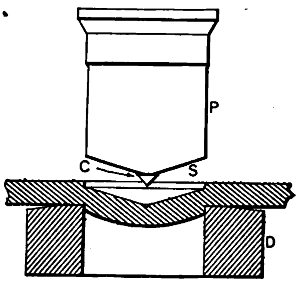

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Figure 65.
A shearing punch.

is also some tearing influence exerted upon the metal while being punched. This influence may extend for a sixteenth or, in some cases, an eighth of an inch all around the punched hole. It is on this account that all punched holes are required to be reamed before the rivets are driven. A sufficient amount of metal should be taken off by the reamer to remove all the affected metal. Although much has been said in condemnation of punching steel and iron plates, yet, in the business world, punching is resorted to and almost wholly depended on. And the failures traced back to the punch itself are few indeed.

Quite a common punch is shown at P in Fig. 64. It is attached to the stud S by a nut N, which holds it firmly in position. C is a center tit, which is now almost entirely used in centering the punch in the work. The die D is relieved at A so that the punchings can readily pass through the hole. In most boiler shops, and in many of the railroad shops, the punch itself is turned from tool steel in large quantities and as it gradually becomes worn out it is annealed and turned down to the next regular size. Then it is hardened and again sent out to be used in the machine. The number of holes that a punch will make depends very much upon the quality of the steel, its treatment in hardening and tempering and also upon the way it is used on the machine. Seven or eight hundred holes will be a fair average for a ¾ or a ⅞-inch punch.

The holes for the tube sheet are sometimes punched and then reamed to size, about a sixteenth of an inch being allowed for reaming. Although one might suppose that it would be an unwise thing to punch the tube sheet holes, yet thousands of them are punched, and in fact one of the leading locomotive works in this country punch every hole unless they are otherwise specified.

Fig. 65 shows a shearing punch which gives a very clean hole and from the enormous number of holes that such a punch can make, it would seem to indicate that the metal was cut rather than torn during the process of punching. This figure shows the shape of the sheet after the punch has advanced about half way on its stroke. When these sheets are punched it is impossible, on account of the construction of the machine, to get close enough to the flange of the sheet unless the flange is turned up toward the punch. This, of course, means that the work of laying out the sheet must be upon the inside instead of the outside of the sheet. C is a spring center; once having centered the sheet upon the punch and thrown the gag of the punch in position, this center presses back out of the way and is always in good condition.

The usual lay-out of tubes is to comply with the specifications; which read "a certain number of tubes spaced so far apart." The bridge between the tubes, see

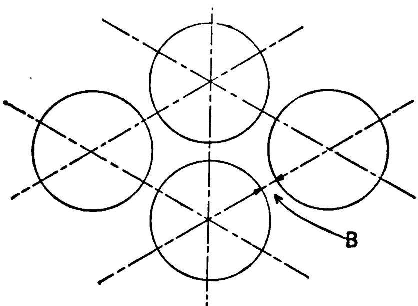


Figure 66

"Layout" for tubes.

Fig. 66 at B, is usually from 5/8 to 11/16 of an inch. Once in a while this space is cut down to one-half of an inch and less. While this cutting down process does admit of a little greater apparent heating surface by allowing a few more tubes, yet the liability of these bridges breaking at B is too great to warrant its being made any less than ½ inch. Then, too, it must be remembered that these tubes are not all straight, that mud collects between them

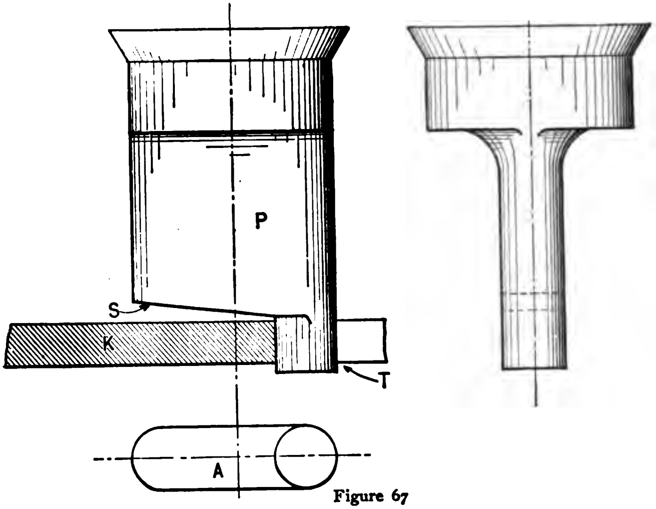


Figure 67

Punch for cutting along curved lines.

and that to fulfill the conditions of a boiler, water should circulate freely about the tubes. The space should therefore be made liberal. The tendency is also toward fewer tubes and more space between them.

One of the most useful things in connection with the punching machine is the cutting punch shown in Fig. 67. It is used for cutting along long curved lines. The shearing machine is used for removing metal on the outside of any curve and the cutting punch for removing the metal on the inside of such a curve. The punch is shown at P, and it is seen to have a tit portion P from ¾ to ⅞ in diameter, and also a taper portion S which is the cutting portion of the punch. The stroke of the machine is

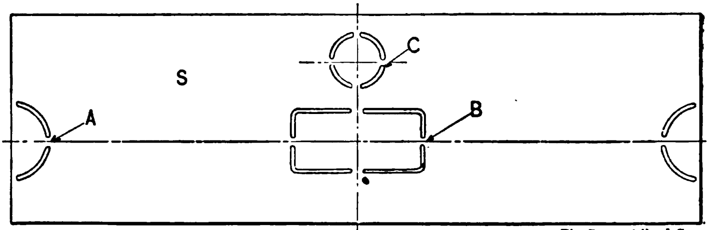


Figure 68
Smoke box sheet with bridges.

such that the tit T always remains in the sheet. As the punch returns, the sheet K is pushed into the inclination S until it touches the tit, when it is ready for the next stroke. S is usually made to cut from 1½ to 2 inches. The plan view of the punch is shown at A being semicircular at both ends.

Fig. 68 shows a smoke box sheet which has been punched with a cutting punch, allowing the bridge A, B and C, to remain in order to make a more satisfactory job of the sheet when it is put through the bending rolls. The necessity for leaving these bridges together with the metal they support will be mentioned again in another section.

The stake portion of a horizontal punching machine is shown in Fig. 69. All flanges as they come from the machine are irregular in shape as will be seen by reference to the line A in the figure. E is the height of the flange that is required to suit the boiler. The sheet is held in position and the metal A removed by the punch and then chipped smooth. Fig. 70 shows a flat punch which does

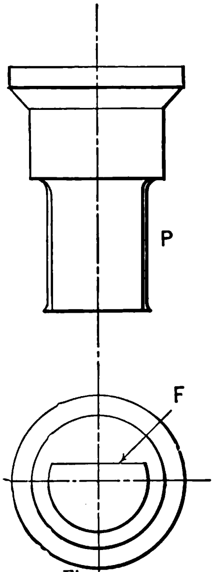


Figure 70 *The Derry Collard Co.*
A flat punch.

not require much chipping after the metal has been punched away. P is the punch and F shows how one side is cut away. A die which is made to fit this punch is designed to go into the same pocket as the regular round die. These punches are rapid and make an exceedingly good job.

Fig. 71 shows a portion of a vertical punching machine, with a sheet P placed in position for punching. The sheet is supported by two clamps from a radial crane as shown, and is raised and lowered by some form of block at H. The operator stands on the near

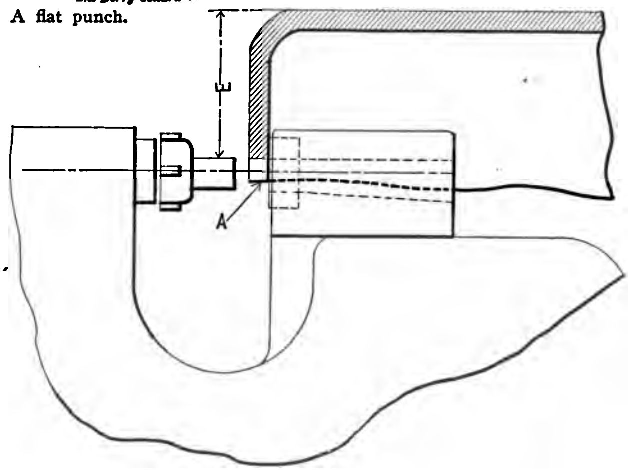


Figure 69 *The Derry Collard Co.*
Stake portion of horizontal punching machine.

side of the machine here shown. The punch has usually both foot and hand lever for controlling the machine.

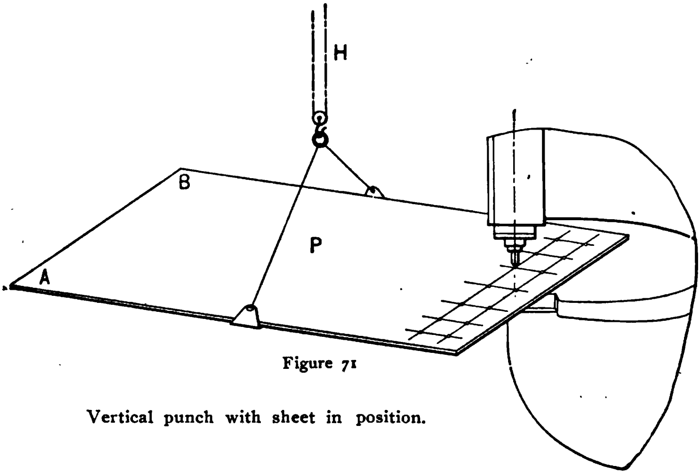


Figure 71

Vertical punch with sheet in position.

The sheet is supported a little out of center so that it rests upon the die.

In order to bring the sheet up to the punch, and enter the tit of the punch into the center punch mark, it is necessary to press upon the sheet at A or B, or both, and overbalance the sheet, thus bringing it up against the punch. The tit should be well entered into the center punch mark. Here lies the cause of so much trouble in punching. The action of the punch is so rapid that if the tit is not entered good and solid in the center punch mark, the hole will be punched through the plate out of center. It not infrequently happens that holes are punched to one side of the center and although this matter may not be so serious in the case of a stay bolt, yet if a rivet hole is punched out of center, it makes a very bad job to fix up.

Method of holding sheet.

Fig. 72 shows the way a sheet is supported over a horizontal punch. An eye bolt E is placed through some punched hole so that it will about balance the sheet and then raised and lowered by a hand crane to suit. T is the

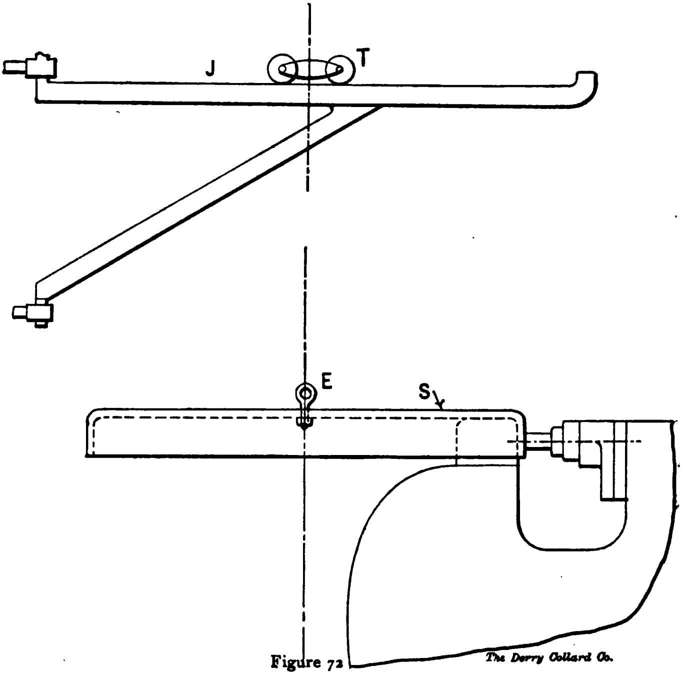


Figure 72

Method of supporting sheet for punching.

trolley which has a movement back and forth along the jib crane J. After the work has been laid out upon the sheet, a good substantial center punch mark should be made in the sheet at every position where a punched hole is required. Before these holes are punched, each one of these places should be given a dab of grease, so as to lubricate the punch and increase its life.

Shearing.

We now come to the subject of shearing. There is scarcely a sheet that does not require some shearing work done upon it at some time during the process of construction. The work should always be laid out in such a

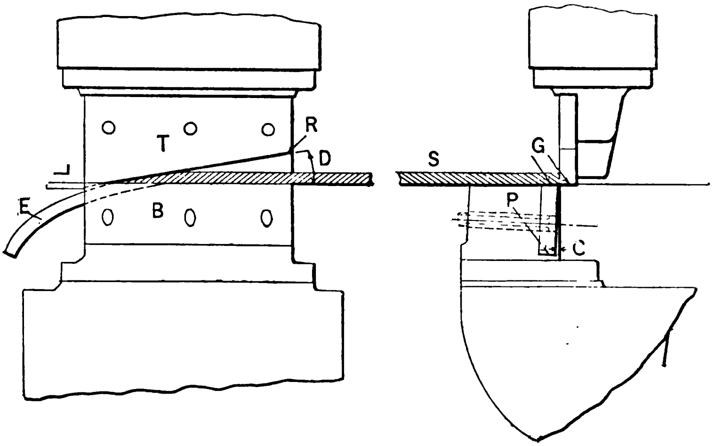


Figure 73
Ordinary boiler-shop shear.

way that the stock can be removed by planing, shearing only being resorted to where the amount of stock is too much to be planed off. Fig. 73 shows the common arrangement of a boiler shop shear. The upper and lower shear blades T and B are made of tool steel and hardened. The blade should always be allowed to lap a distance at L, which is usually about a quarter of an inch when the head of the machine is in its highest position. As soon as the blades wear down so that they will not lap at L, they should be packed up; an adjustment always being pro-

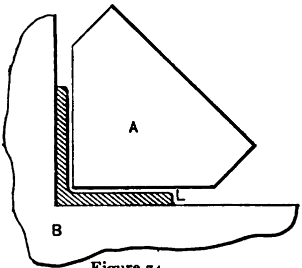


Figure 74 The Derry Collard Co.

Angle iron shear.

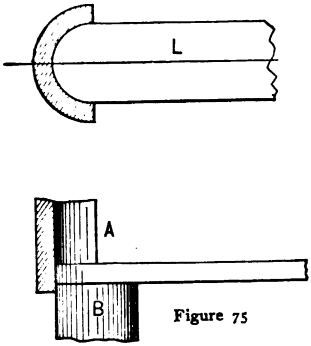


Figure 75

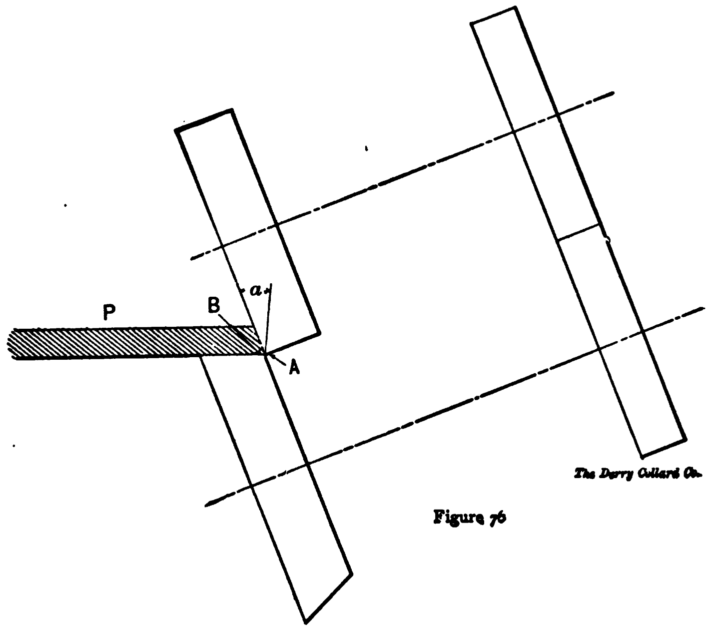
Shear for crown bar stays.

vided for on one blade or the other. The lower blade is usually set at a slight angle of about 1½ degrees at C. When the stroke of the machine is large, the corner of the upper shear blade should be ground off so that the upper portion of this curve will not sink into the top of the plate, when the head is on its extreme downward stroke.

Many boilers require angle irons in different parts. They are very quickly cut off in an angle iron shear, as Fig. 74. A is the upper and B the lower die. Any size angle iron L within the capacity of the machine can be cut off with the shears.

The crown bar stays are usually made of material

½ by 2½. These are very conveniently cut from the bar by a shearing arrangement shown in Fig. 75. The upper portion has a semi-circular shear blade A which passes by



Rotary shear for thin sheets.

the lower blade B. The material is pushed into the machine against a stop and the ends are sheared off circular as shown.

Where the boiler sheet is very thin as where the material is used for tanks and for air drums, the rotary shear shown in Fig. 76 is satisfactory and is rapid. The shears are set at a fixed angle and all sheets are sheared with the same inclination of the edge. The one great advantage in this form of shear, is that any curve can be rounded by it, a feature that is impossible with a plate

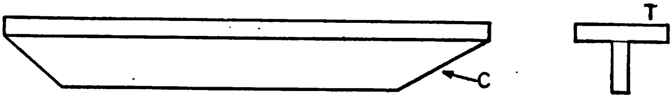


Figure 77

A crown bar.

planer. The edge of the plate comes from the machine rather rough and a little bit ragged, but when the sheet is in position and calked it makes a good job.

In Fig. 77 is a crown bar. When these crown bars are made of light T iron, they are readily sheared along

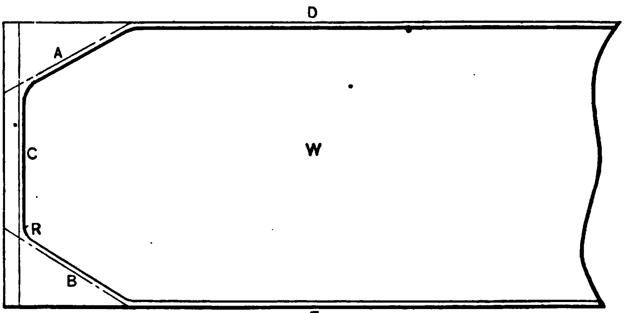


Figure 78

A welt strip.

the line C on any punch, where the flange can be butted up against the shear blade. The large size T iron, however, cannot be sheared. The short pieces are cut from the bar either by a cold saw or else by nicking with a sledge and cold chisel, and then breaking either by hand or

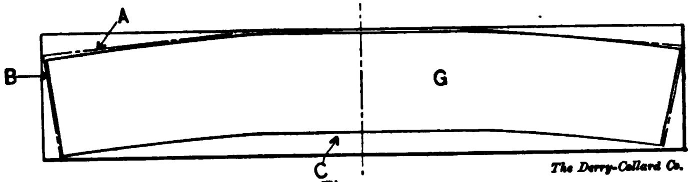


Figure 79

A gusset.

a hydraulic bender. The portion at C in this case being either shaped off, or cut off after heating in the forge.

The welt strip, Fig. 78, is laid off with only enough

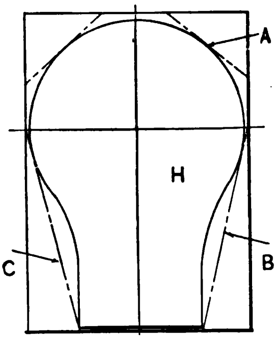


Figure 80

Back boiler head.

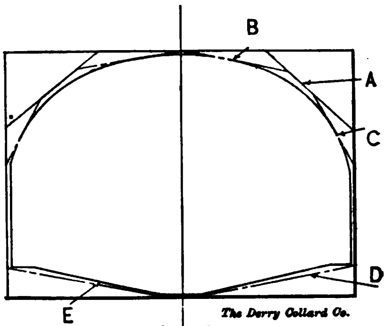


Figure 81

Throat sheet of Wooten boiler.

stock at D for planing. The plate W is then taken to the shear and while being swung from a jib crane it is sheared along the line A, allowing only enough metal for planing. The plate is then turned a little further around and sheared along the line C. Next it is thrown around and sheared along the line B. The corners at R can be nipped off under the shears to suit the radius. The stock along the lower line E is usually ordered so that it will not need to be sheared. If, however, the amount of metal to be removed is more than ¼ of an inch, it should be sheared off.

The gusset shown on Plate 4 is seen in Fig. 79. It is sheared along the line A on both sides and then along the line B. The metal at C, on account of the curvature, will have to be removed by the cutting punch. Fig. 80 shows the back head of the boiler shown in Plate 2. The plate usually comes in from the mill shaped as shown by the lines in this figure. If the sheet is rectangular, however, the metal will have to be removed along the lines A and B. The corners will then be clipped off to the line laid out on the sheet. The metal along the line C is removed with a cutting punch. The inside throat sheet of a Wooten boiler is shown in Fig. 81. It is sheared along the lines A, B, C and D. The extra metal at E being removed either by planing or by cutting away with a punch.

Plate Planing.

The plate planing machine is so powerful that whenever it is possible to plane a sheet at all it should be put on this machine. It gives a better edge to calk against than can be obtained in any other way. Then too the lines are straight, improving the appearance and lessening the cost of fitting up. The butt seam of every course of the boiler should be planed square, and all the calking edges along the longitudinal and other seams should be beveled off to a calking angle.

Fig. 82 shows a seam where one sheet is square and the other sheet is beveled off for calking. The angle is different in nearly every shop. In many places it is gaged

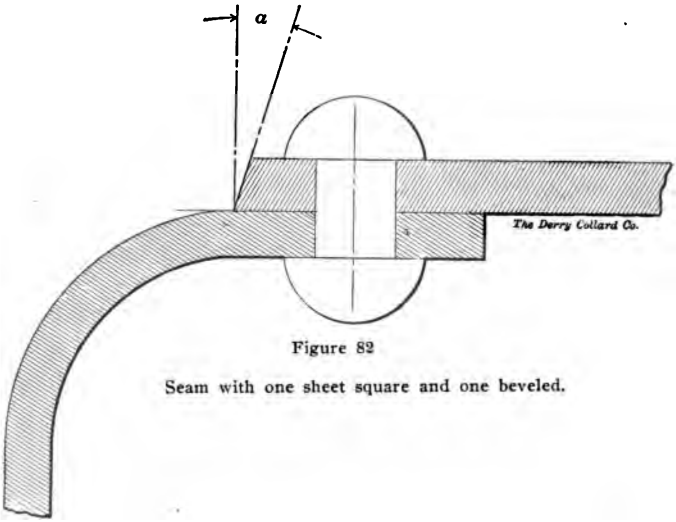


Figure 82

Seam with one sheet square and one beveled.

alone by the eye, while in others templets are made and rigidly adhered to in planing. For a ⅝-inch sheet the bevel would be from $^3/_{16}$ to ¼ inch.

There are many different ways of holding the sheet in place while it is being planed, and there are also many ways of lining up the sheet for planing. Fig. 83 shows a boiler plate which has been punched, and is now ready to be planed. In nearly all shops the pitch of the rivets for the various size plates and seams is figured down to a standard, and for given conditions the distance L is always the same. For this reason a gage of whatever form or shape it may be, is made to drop into one of the rivet holes determining the distance L.

Fig. 84 shows such a gage. They are marked for the different seams and dropped into the punched holes A_1

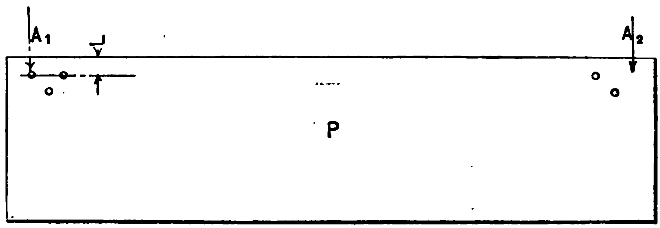


Figure 83

Plate ready for planing.

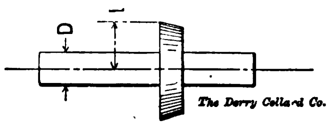


Figure 84

Gage for plate planing.

and A_2, near the ends of the sheet. After the jack screws have been drawn up tight, the head of the plate planer is started out along the edge of the sheet and a cut is taken off. This process is continued until the planer tool just touches the gage.

Fig. 85 shows a portion of the plate planer, P is the plate, which is held firmly upon the bed of the machine B by the jack screws J. When the sheet P is short so that only one or two jacks can be used upon it, it is liable to be torn from underneath the jacks by the action of the tool. A piece of wood placed between the screw S and the plate, will hold the plate firmly in position under almost any condition of planing. G is the beam of the planing machine.

The butt joint of the first course of a boiler is shown

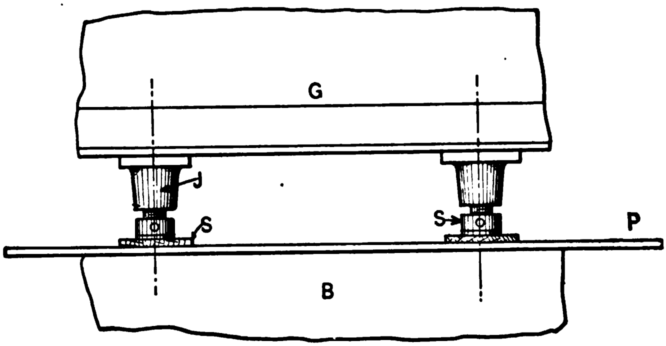


Figure 85

How plates are held for planing.

in Fig. 86. This represents the condition of planing along the edge for cases where the seam is welded for a short distance on the ends. The sheet is first lined up by the gages being dropped in the holes B. The jacks are then lowered and the plate held firmly in position. The square planing tool is run along the edge and one cut after another taken, until the edge is brought down to gage. The angle tool is now started and allowed to run the required distance along the edge then quickly withdrawn, until the edge is beveled off at A, to the required distance. This angle is usually made 45 degrees.

Fig. 87 represents a dome sheet. This is a sheet for one of those domes where the vertical seam is butt riveted. This sheet has already been punched, and is now ready for planing, which is the last operation required before going to the bending rolls. B and B are any two rivets holes along the top line. This sheet is then clamped and planed down to gage. The clamps are raised, the sheet turned around and gages dropped in the holes at A.

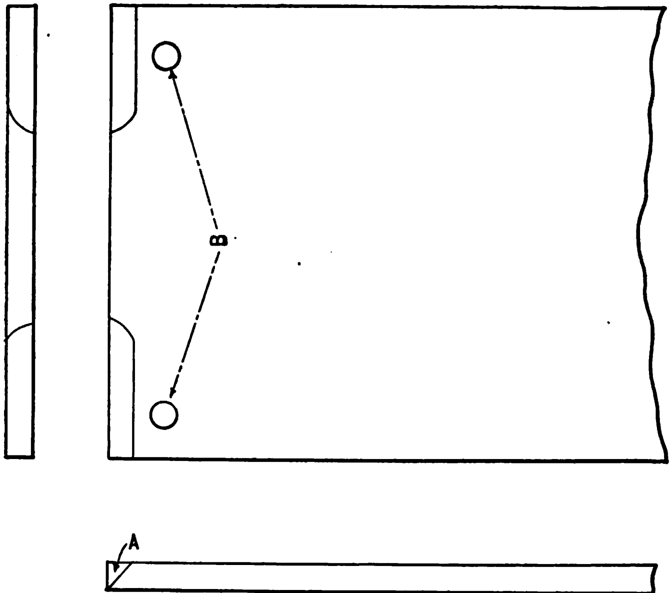


Figure 86 The Derry Collard Co.

Butt joint of first boiler course.

It is now clamped and planed along the edge. The other edge of the sheet is planed in a similar way. The lower edge of this sheet at D cannot be planed unless the curved line varies but little from a straight line, but as most of these domes are very large, and consequently reach down a considerable distance along the side of the boiler, the

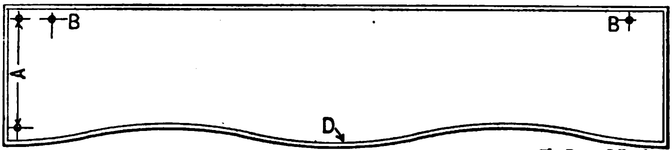


Figure 87

Planing a dome sheet.

line D has quite a marked curve to it; this must be chipped.

The fire-box throat sheet of Plate I is seen in Fig.

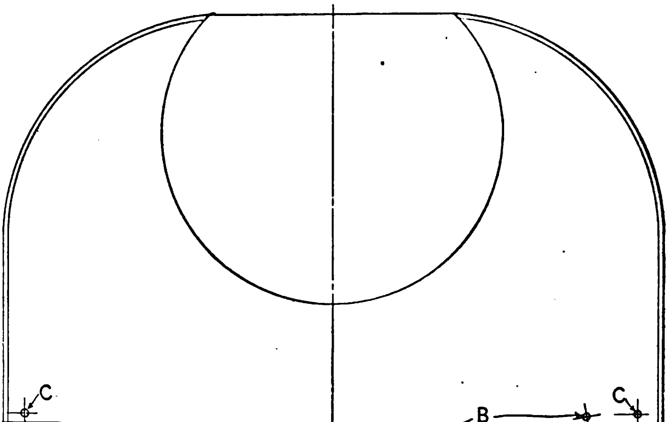


Figure 88

Planing a fire-box throat sheet.

88. This sheet should be planed along the lower edge before flanging, and as the lower edge is usually kept ¼ of

an inch from the lower line of the water space frame and must be calked, the sheet will be planed at an angle.

The first operation would be to line the sheet up from the holes A, and then the short flat spot can be planed off the proper amount. Next the clamps are undone and the sheet is barred around so as to line up with the holes at B. The planer tool is then run along this line and when the lower kink of the line is reached, the tool must be withdrawn; in the same way the other incline line of the sheet is planed. The sheet is then thrown around and lined up with the holes C and C, and this line, although very

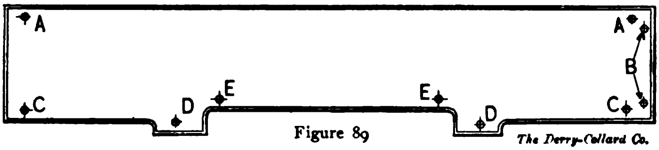


Figure 89

A difficult sheet to machine.

short, will be planed and the tool withdrawn promptly at the end of the stroke, so as not to cut into the sheet already planed up. This sheet is now ready to be flanged.

Sometimes we find on a boiler a sheet like that shown in Fig. 89. The sheet is rather a difficult one to machine on account of the irregular shape of the edge. The metal having been removed so as to allow sufficient stock for planing, the sheet is brought to the planing machine and lined up by dropping gages in the holes A and A. This edge will be run along with the angle tool and planed to the line. Next the sheet will be thrown around, lined up at B and this edge planed with a square tool. Then the other edge of the sheet corresponding to B is treated in a similar manner.

The sheet is now lined up at E and E, and the throw-out dog is set along the shifter rod so as to stop the planer tool a short distance from the square shoulder. The head of the planing machine is now run backward to the other end of this line and the throw-out is set to suit. This line is now planed to the gage and what remains will be chipped out. The plate is then lined up at C and C, the planer tool started along the lower edge and the throw-out arranged so as to keep the tool from digging in the offset at D. In the same way the other end of the

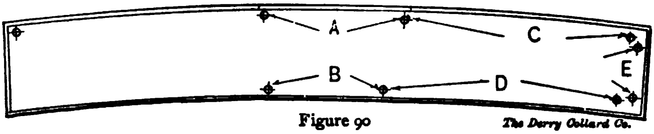


Figure 90

Handling a gusset sheet.

line is planed, the tool being rapidly withdrawn at the end of the stroke, so as to break off the cut. The metal which remains will have to be chipped out. The sheet is then lined up at DD and this line planed off at the required distance. All the planing along the lower edge will be at an angle. The usual form of gusset sheet will be seen by referring to Fig. 90. This sheet, it will be remembered, has a very flat portion front and back, around the bottom center line and therefore the planer tool can readily be made to plane at least 2 feet at these places. This sheet will be brought to the planing machine and lined up at the holes A. Of course it will be remembered that all of the holes which have been indicated in these figures are but a few of many others which have been punched into the sheet. Two of these holes, which would best suit our purpose, would be chosen to line up by. The sheet is now planed along the line A.

The curved line along the sheet between the holes C, varies more or less from a straight line, depending upon

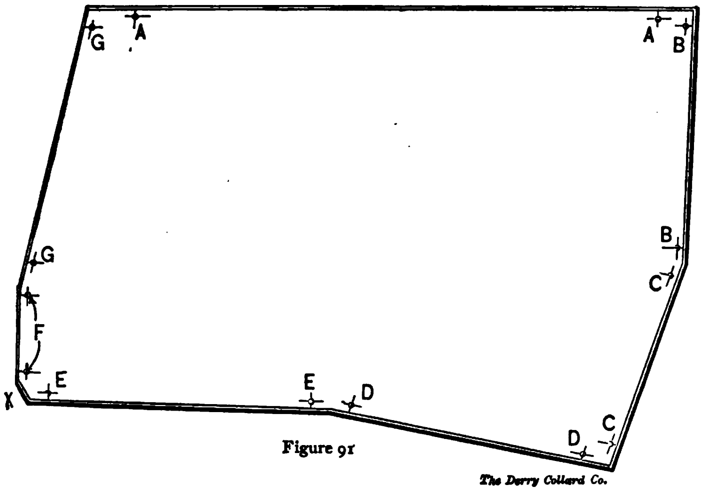


Figure 91

Planing an irregular sheet.

the conditions upon which the boiler is constructed. The sheet is now lined up by the hole C, and having laid off the line to which the sheet should be planed. The head of the planing machine is started along the line and the tool fed in or out to suit this line as nearly as possible, the curve running out along the straight line at A.

Next the sheet is planed on the opposite side to C, then it is thrown around on the end and planed along the line E. This line, it will be remembered, is not straight and therefore the planer tool must be withdrawn so as not to dig into the inclined portion of the sheet at the end. The whole length of this line, including the parts that run at an angle, can usually be planed, but if the inclination of the gusset is very great, this angle becomes very large and one side would then have to be chipped out. The same thing is done at the other end of

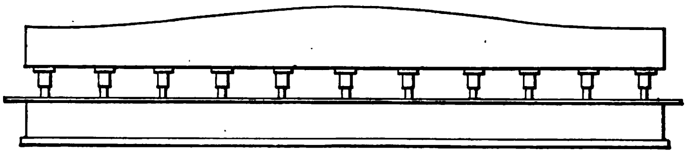


Figure 92

Front elevation of plate planer.

the sheet. The sheet is now thrown around and lined up at the holes B, then planed along the line. It is then lined up with the holes D and, as this is the concaved line, the tool must be fed into the sheet through the first half of the stroke and withdrawn during the latter half. The desired line is laid out on the sheet and planed to as nearly as possible.

We will refer to Plate 3 for another example of a very irregular shaped sheet. This sheet will be seen in Fig. 91. All the holes in this sheet will be either punched or drilled as it comes to the planing machine, so we can readily select a pair of holes A, A, and bring the sheet into place to correspond to them. All the lines on the sheet will be planed for a calking edge. The line along A will be planed at an angle. Next the sheet will be lined up at B, and planed off to suit. In a similar way it will be planed off along C. As the lower line of this sheet is concaved, the planer tool will have to be withdrawn and

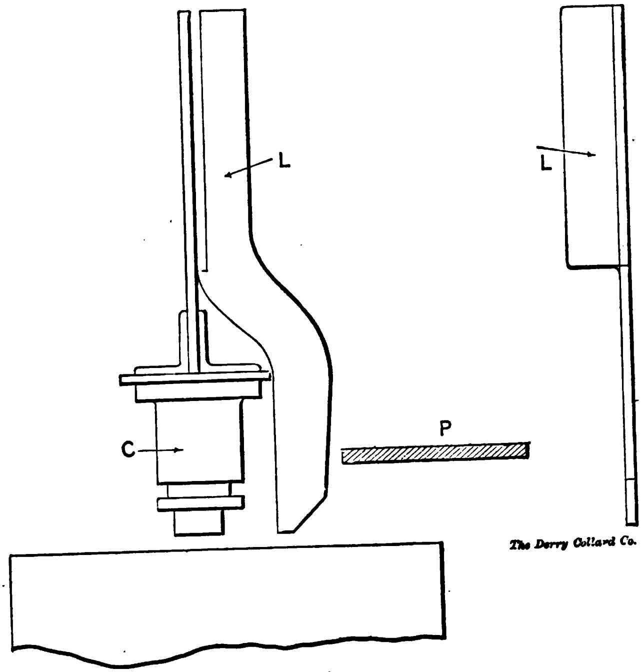


Figure 93

Hydraulic jack for holding plates.

the throw-out set to end the cut with certainty, before it can enter the sheet along the line E, E. In the same way the line E, E, is planed. What remains in the corner between E and D must be removed by chipping. The sheet is now planed at F and G. If the beveled portion of the sheet at X is more than 5 or 6 inches, the sheet would be clamped in the machine and this portion planed off.

Fig. 92 gives the front elevation of a plate planer with the sheet held in position by a series of jacks. I would like to mention in connection with these jacks that in an attempt to get a clamp that would not slip, these jacks have been made so powerful that they lifted the foundation bolts on the ends of the machine. This was due to the fact that when a beam is loaded it bends and the beam, being a bed in this case, could only bend by raising the foundation bolts. No trouble is found in large sheets, but in holding very small sheets where only a few jacks are brought into play.

A good plan is to have several extra screw jacks which can be placed in between the fixed jacks, to help in holding very narrow sheets. These jacks are now frequently made to operate by hydraulic pressure, which saves time. On account of the elasticity of the accumulator pressure, they act like a spring and will follow up any irregularity of the spring of the beam, always keeping tight, which cannot be said of the screw jacks. Hydraulic jacks have proven quite satisfactory, although being fixed they do not lend themselves to being shifted close together and made to hold a narrow sheet.

One of these hydraulic jacks is shown in Fig. 93. L is an angle iron which is bent down in front of each jack on the side of the machine facing the crane. It acts as a guard for the cylinder and prevents it from being damaged by the sheet as it comes swinging into place. Some of these sheets are very heavy and a number of cylinder repairs have been made necessary by bumps of this kind.

Bending.

All the operations heretofore referred to must be performed upon a sheet before it is ready to be bent. All sheets which are cylindrical when bent are usually easy to bend, but the gusset sheet and the crown and side

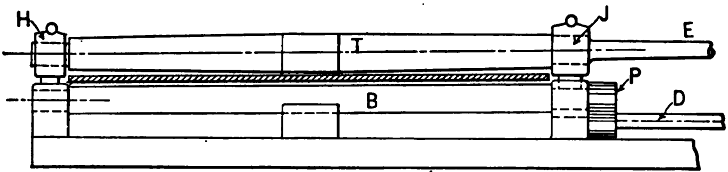


Figure 94

Front elevation of bending rolls.

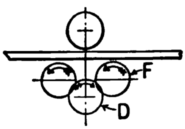


Figure 95

Showing how rolls are driven.

sheets often make very difficult problems. A bending roll is shown in Fig 94, with a sheet in place. Before the sheet is bent, it is pushed directly into the rolls or pulled straight out from them. When the sheet is bent to form a cylinder, it must be slipped off of the end of the rolls. This is done by a hinged bearing H which swings out so that the sheet can be removed. There is one top roll T placed in the center, and two bottom rolls B, one on each side of the center. These rolls are driven by pinions P.

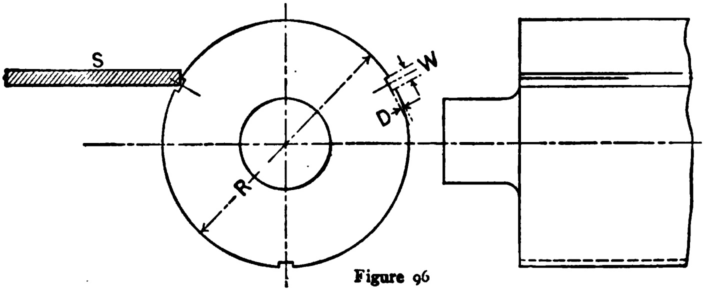


Figure 96
Position of slots in bottom bending roll.

The action of the pinion is seen in Fig. 95. D is the driving and F the following pinion, which are keyed to the two bottom rolls. While the plate is being received the top roll must be supported by an arm E. This arm extends to the far end of the machine. It can be held in any position by a screw and hand wheel, and the bearing H dropped out of place.

The two end bearings H and J of the top roll can be adjusted up and down independent of each other. By throwing a clutch lever back and forth, one is able to raise or lower one or the other, or both ends of the top roll. It is by this adjustment that we are able to roll a conical sheet. It will be seen that a small portion of the top roll is straight. The ends are tapered off by an amount which is proportional to the size and length of the machine. This is to offset the spring of the roll. On account of the construction of the machine, it is impossible to roll any gusset sheet without bumping or barring the sheet around in the rolls. The lower roll being fixed, one end of the sheet would naturally roll as fast as the other, which of course would not do for a conical sheet. On account of this adjustment and for several other reasons, the bottom roll should have at least one, but better have three slots in it as indicated in Fig. 96. These slots are used to line up the sheet.

Take the case of a cylindrical sheet, which is the simplest case of bending. We must get this sheet started straight, otherwise when the two ends come together they will not match up. This is a matter which is not

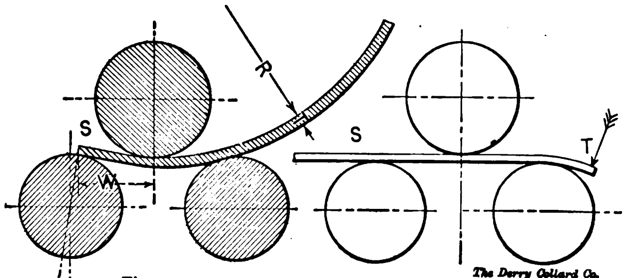


Figure 97 Figure 98

Sectional views of bending rolls.

easily remedied, as the sheets are all planed off square on their ends before being bent. The sheet can be pushed in against one of these slots, thus lining it up perfectly straight. A slot ¾ of an inch at W and ¼ of an inch at D would answer the purpose very nicely.

In the absence of these slots, a chalk line is very convenient. It is held at each end of the roll so as to line up with the center, and then snapped, the white line is readily seen and makes a good substitute for a slot.

A sectional view of a bending roll can be seen in Fig. 97. T is the plate and R the radius to which it is bent. When the sheet is entered, the power is turned on the bending screw, and the top roll is brought down so as to bend the sheet. The machine is then run back and forth and by gradually lowering the center roll, the proper radius R is obtained. This style of bending roll always leaves a flat portion of the sheet at S, which is not bent to the radius R. The reason for this is that the plate is a beam, supported at the two ends and loaded in the middle. The greatest bending moment is, of

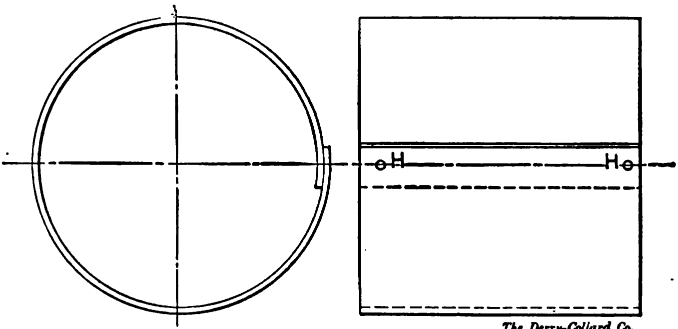


Figure 99

Bending a cylindrical steel.

course, under the load and here is where the sheet bends.

While the portion W, as would be the case with any other beam, will remain straight. This is ordinarily no objection in boiler work, for it is here that the seam is made and a flat portion in the sheet at the seam will not do so much harm, especially if it is a single or double riveted seam.

Sometimes it is desired to have the sheet bent clear to the edge and there are many cases where this is not only desirable but absolutely necessary. In this case,

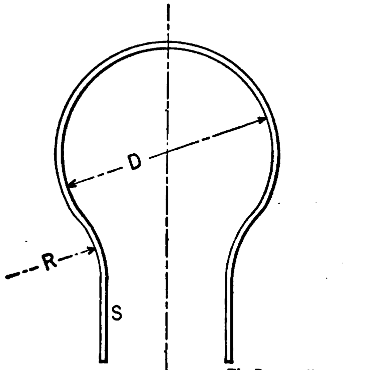


Figure 100

Development in bending a sheet not wholly cylindrical.

Figure 101

the sheet is supported as in Fig. 98. The sheet is entered into the bending rolls, and an amount allowed to project at T, which would ordinarily remain straight. The top roll is now lowered and the sheet is firmly clamped in this position. It is now bent to the required radius by pounding upon it in the direction of the arrow. By applying a gage one is gradually able to get the required radius. Ordinarily this can be done cold, but if the bend is very sharp, the sheet must be heated along the edge and hammered down with a wooden maul.

Fig. 99 represents a cylindrical sheet, which has properly been rolled into place. The sheet is first entered into the rolls and lined up either with the slots or a chalk line, and then the ends of the sheet are rolled to conform to the required radius. The sheet is then rolled back and forth and the top roll lowered until the ends are brought together as here shown. The holes H and H as well as the edge of the sheet must coincide.

We will now consider the bending of a sheet which is not a cylinder. The sheet is shown in Fig. 100, which represents an outside sheet of a boiler, and which has the same shape front and back. This is not an uncommon sheet on a locomotive boiler. It is straight for a short distance S and then follows a radius R, which follows the line of the diameter D. This sheet is first entered into the rolls and the tangent points of the radius R are marked, a gage is then bent to conform to this radius and the sheet is run back and forth in the rolls, the center roll being lowered so as to give the radius R_1 in Fig. 101. The other end of the sheet is treated in the same way.

The sheet is taken from the rolls and turned upside down, as shown in Fig. 101. Having the top roll elevated, the sheet is now entered and the top center line of the sheet is lined up with a chalk line or with grooves in the rolls. The sheet will have to be bumped back and forth until this comes exactly right. The top roll is lowered and the sheet runs back and forth until it gradually assumes the shape shown in Fig. 100.

In regards to this shape, a caution may not be out of place. When the fire-box of the boiler sets down below the driving wheels, and where the space between the driving wheels and the fire-box is limited, the radius R

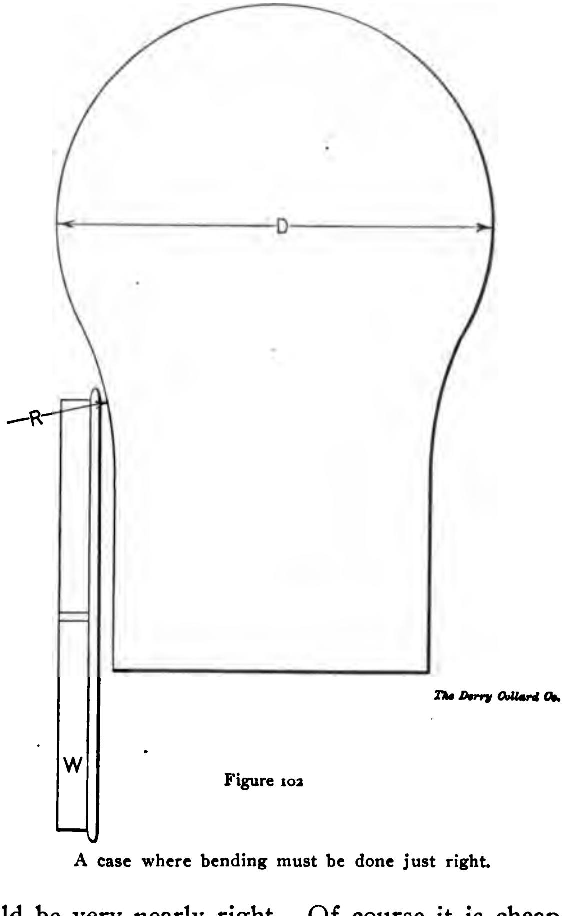


Figure 102

A case where bending must be done just right.

should be very nearly right. Of course it is cheaper to use an old die and patch it up a little, to flange the head, even if the condition has been slightly changed from the figures on the drawing. But in the case shown in Fig. 102 the head must be nearly correct to the figures given in order that the boiler will drop in between the wheels with a sufficient room to clear the driving wheels. There have been cases where mistakes of this kind have occurred, and to fix such an error, which is only discovered when the boiler comes to the erecting shop, is not an easy job. All the stay bolts in a spot around the flange of the wheel must be drilled out, the sheet heated up on the outside to a dull red, and then pounded back a sufficient

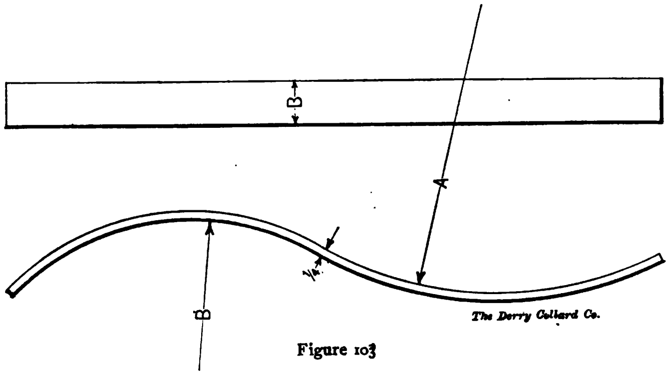


Figure 103

Gages for use in bending work such as shown in Figs. 100-102.

distance to clear the flange. The holes must be re-bored and large stay bolts put back into place: Beside all this work it makes an unsatisfactory job.

When any sheet like the one shown in Fig. 100 is to be rolled, wrought iron gages are bent to suit the curvature. Then the plate is rolled to these gages. They are usually made of strap iron ¼ inch thick by 2 inches wide. One of these gages will be seen in Fig.

103. As this iron is very light and easily bent one of the pieces is taken and bent by trial to the boiler; it is bent to suit the contour. The gage is then marked to suit the boiler to which it applies.

In the case of a fire box, crown sheets or side sheets and where the front and rear ends are not the same, a gage is made for each end of the sheet. As the dies for

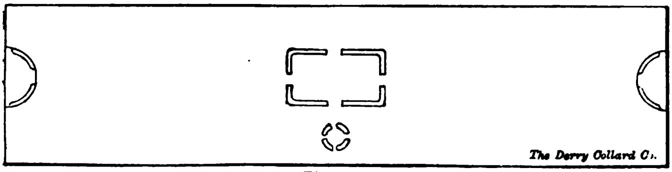


Figure 104

Smoke box sheet with bridges left in holes.

the front and back sheets of the fire box determine the size and shape of these sheets, this gage must be hammered and bent to suit the outline of the flanged sheet.

In the section on punching, reference was made in regards to allowing a certain amount of metal to remain until the sheet had gone through the bending roll. Fig. 104 shows a smoke box sheet which is punched and planed up along the edges, ready to be bent in the form of a cylinder. If the bridges here shown were not allowed to remain, the sections through these holes would be much weaker than through the solid plate, and as the plate, during the process of bending, is a beam supported at either end and loaded in the middle, the maximum bending moment is under the center of the center roll. It is evident that if large holes are cut into the plate the plate will bend more in crossing the hole than it will in the solid plate, but if these pieces are allowed to remain we have the equivalent of a solid plate. They are readily drilled out after the sheet has been rolled. Of course this is only done when the holes are of such large size that a uniform bend could not be obtained otherwise.

When a conical shaped sheet is to be rolled, the sheet must be lined off at intervals as shown in Fig. 105. This represents a slope sheet of the boiler. The center line C, C, has already been laid out, as well as the quarter lines D, D. As the sheet will come to the rolls all punched, lines as E, E can readily be laid off from the rivet holes. A line should now be chalked and a chalk line snapped at

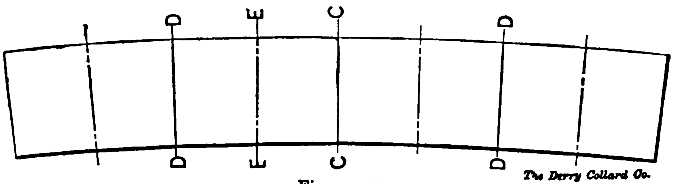


Figure 105

Lining off conical sheet before rolling

each one of these places. The sheet is now entered into the rolls and straightened up with the first chalk line. It is then run back and forth a short distance on each side of the line and then the top roll is released. The sheet is then bumped around so as to be straight with the next line and so on until the two ends of the slope sheet gradually work their way together. If an outside crown sheet of a Belpaire boiler, Fig. 106, was to be bent, a gage would be made to conform to the shape of the front end of the sheet, and also one for the rear end of the sheet. This sheet would be entered into the rolls and after having a center line marked on it would be lined up to the rolls by this center line.

The top roll will now be brought down slightly out

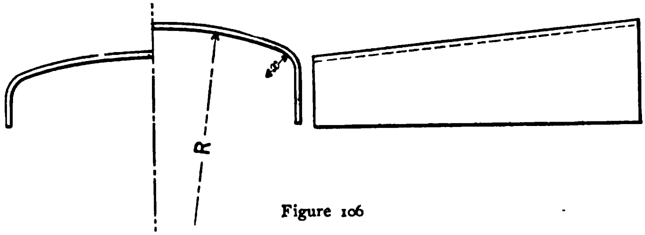


Figure 106

Crown sheet of Belpaire boiler.

of level and then this sheet must be run back and forth along the center, occasionaly running the plate far

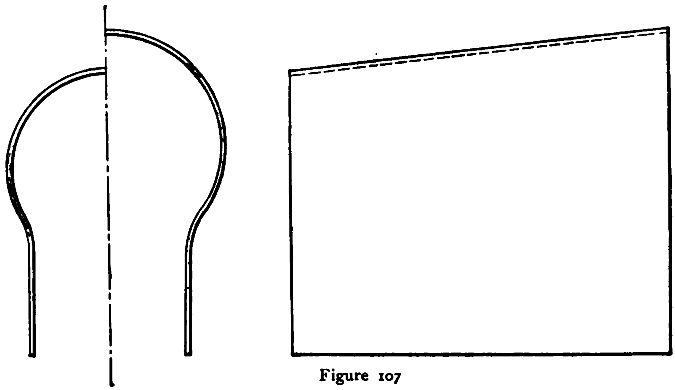


Figure 107

Crown and side sheets.

enough through so as to be able to apply the gages front and back. By carefully manipulating the top roll and also watching the sheet so as to keep it lined up properly the curvature of the sheet will gradually be made to creep around to and finally conform exactly with each gage. If the radius X is small, this sheet will be flanged on the ends by heavy wooden mauls.

A fire box crown and side sheet is shown in Fig. 107. As the front and rear end of the sheet are different in shape it cannot be run straight through the bending rolls. This sheet like the gusset sheet already mentioned must have a center line laid off on it. Then all the quarter lines, and at least one intermediate line between the quarters must be laid off. The sheet is first entered into the rolls and the ends of the sheet are cut to conform to the gauge. After both ends have been treated in this manner the sheet is removed, turned upside down and re-entered into the rolls. It is then run back and forth and hammered around to line up with the various marks that have been drawn on the sheet, and the sheet gradually bent to conform to the gages for the top portion of the boiler.

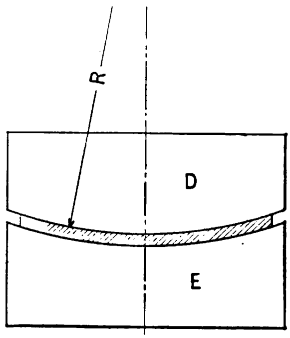


Figure 108

Dies for welt strips.

Welt strips are usually much too narrow to be bent in the rolls; they are usually heated and then pressed between dies D and E, Fig. 108, either under a hydraulic flanging press or under a horizontal bending press. The dies do not necessarily have to be the radius of the boiler, the nearest die being selected and then, by putting pieces of sheet iron in the center joint, the edges of the welt strip are bent to suit another radius.

Not all of the power bending rolls are capable of

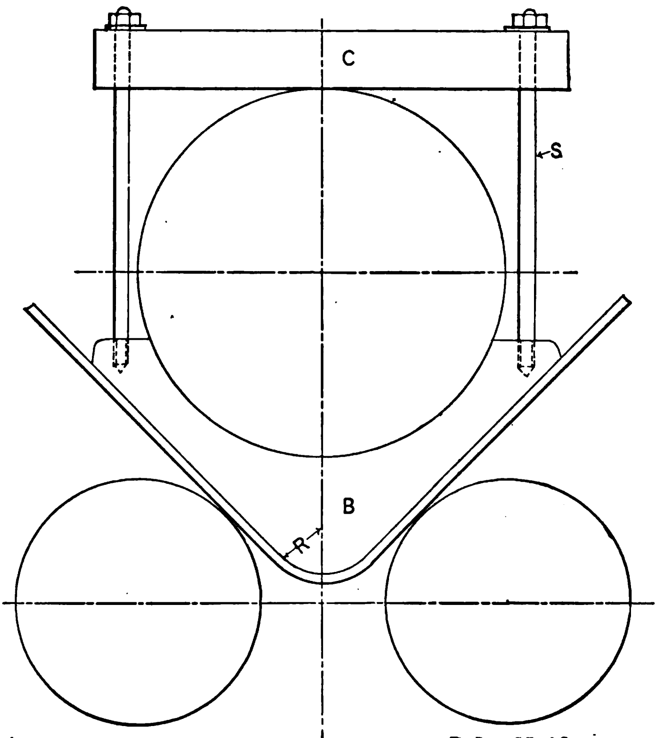


Figure 109

A handy way of using bending rolls.

bending a sheet as seen in Fig. 109, but when the sheets are not so thick and when the rolls are powerful, the corners of a Belpaire crown sheet can be bent cold by bringing the top roll down against the bottom rolls and punching the sheet between them as indicated. B is a rough casting with studs S screwed into it. C is a piece of wrought iron bent around so as to form a clamp. By this means almost any radius R, within the limit of the machine, can be obtained. Fig. 110 shows a very large

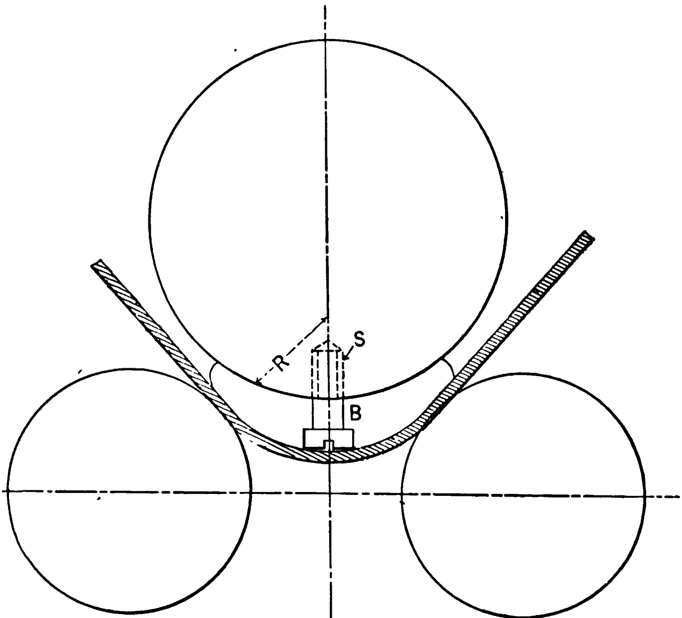


Figure 110 *The Derry Collard Co.*

Another use of bending rolls.

radius which is obtained in the same way. B is also a rough casting and held to the rolls by cap screws.

Sometimes a spiral seam is required for certain work, especially in the air reservoirs of air engines where the pressure is very high. As the heavy welt strips that would be necessary for this pressure would make a diffi-

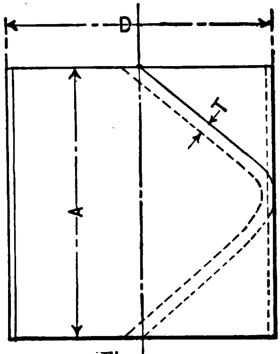


Figure 111
The Derry Collard Co.

A spiral seam.

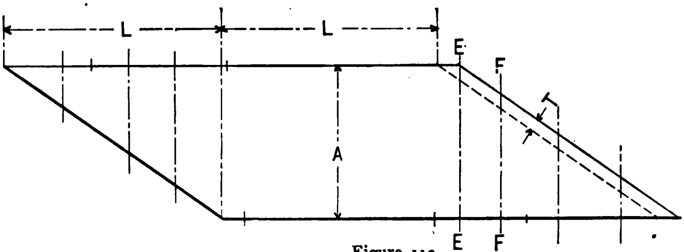


Figure 112
The Derry-Collard Co.

Sheet for spiral seam.

cult construction, the seam is made single or double riveted and is run spirally around the boiler. Fig. 111 shows such a sheet.

It is shown developed in Fig. 112. This seam half encircles the boiler on the developed sheet. The distance L is equal to one-half the circumference of the neutral diameter D. A is the length of the sheet. At any section of the boiler the length of the sheet is a complete circle, plus the width of the seam. Another distance LL is laid off from the first, completing the circumference. In addition to this, we have the width of the seam T. Lines E, E, F, F, and so on, are drawn across the sheet as shown. After the sheet has been planed up, punched, drilled, etc., it is entered into the rolls and run back and forth. It will require occasional bumping around to bring these lines parallel with the rolls. The ends gradually work around and point toward each other and gradually work together until the seam commences to lap over. The ends should be rolled exactly to the radius of the boiler before the seam commences to close in as the rolls cannot be allowed to run over the seam on account of the extra thickness of such a plate.

Machining Parts.

This section treats all machine work which is not included under the head of Punching, Shearing, Planing, etc.

Drilling.

In many shops the holes for the tubes in the front and back tube sheets are punched to about ¾ or ⅞ diameter before the sheet is flanged, except a few which are located so close to the flange that there would be danger of drawing during the process of flanging. After the sheet has been flanged and the rough edges trimmed off, it is put under a radial drill and a bar B, like that shown in Fig. 113, is let down through the punched hole at D. A cutter L, whose length is equal to the diameter of the hole for the tube, is keyed to the bar by a key K. All the holes are then bored out to this diameter. The cutter and bar being steadied by the guide D in the hole.

There are many rings about a boiler varying in size which have radial holes drilled into them. An example of this kind is the smoke box ring, intermediate ring and dome cap ring. Fig. 114 shows a simple yet a very good method of doing it. E and E are rollers supported in some way from the table of the drill press. A good way of supporting these is to tap studs into an angle iron and then the angle iron is clamped to the face of the drill press. In Fig. 114, R is the ring and

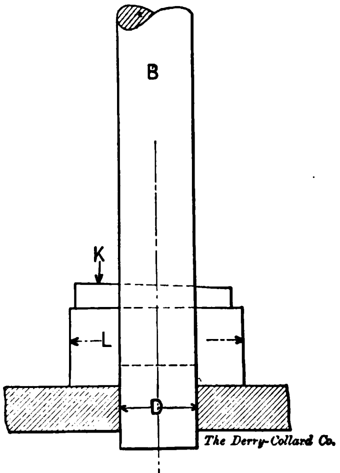


Figure 113

Cutting holes in tube sheet.

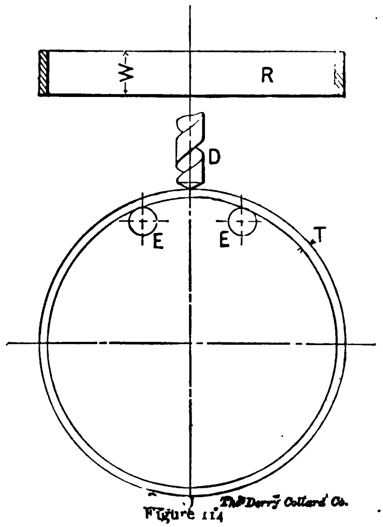


Figure 114

Drilling radial holes.

D is the drill. After a hole is drilled the ring is rolled on E, E, into the next position, and so on. All holes must of course be radial, if the rollers E, E, are level. A pit is usually provided on one side of the drill press, so that work of a large diameter can be lowered into it.

Radial drill work.

This work is frequently done by a radial drill, which can readily be swung around. Having a pit on one side of the machine for large work, they are at the same time

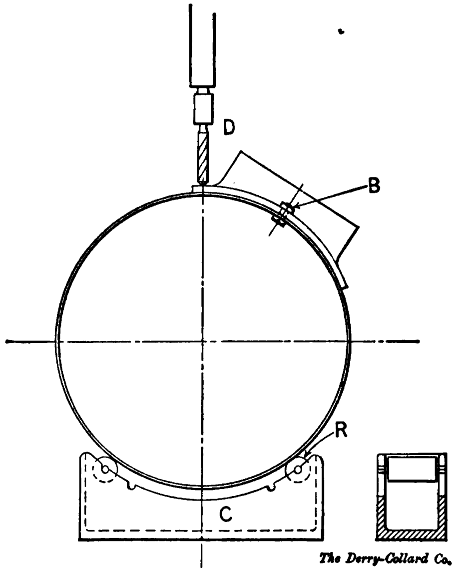


Figure 115

Drilling dome flange.

provided with a base on the other side of the machine for small work.

On account of the very large hole which is cut into the sheet under the dome, the boiler is weakened at this point, and to make up for this the dome flange is made heavier than the other sheets, and is always double riveted along the part which is fastened to the boiler. These flanges are usually made of 1⅛ or 1¼ steel and cannot be punched. Fig. 115 shows the method of drilling these flanges in position. In this case, the holes are laid off from a templet on the outside of the dome flange. A deep center punch mark is put into the sheet for each

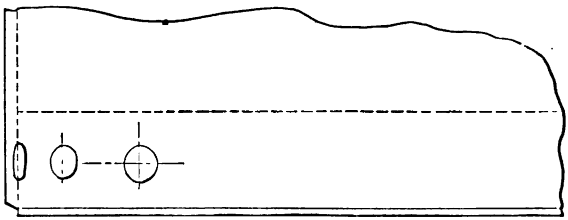
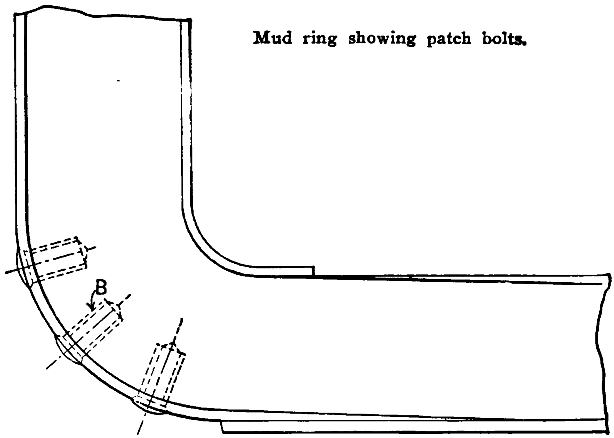


Figure 116

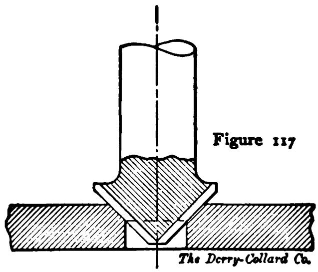


Mud ring showing patch bolts.

hole and the drill is run through both the flange and the boiler sheet. The dome is held in position by two bolts B, one front and one back.

When this flange was in the press the center line was marked with the center punch. The dome is now lined up on the boiler to suit these marks. The two holes front and back will be drilled, first through the flange and then scribed off and drilled through the sheet. C is a cast iron cradle into which a pair of rollers are dropped so that the boiler can easily be rolled back and forth. There are two such cradles, one at each end of the boiler. Several notches are provided for the rollers R to suit the various diameters. This work would be done under some form of radial drill, the saddle of the drill being shifted back and forth, while the boiler is rolled in the cradle. Thus in turn, each one of the holes of the flange can be reached and drilled radially.

In Fig. 116 will be seen the corner of a water space frame. The patch bolts B are drilled with a compressed air drill or some other portable drill. After the mud ring



Rose reamer for countersink.

has been entered into place, the holes are drilled twice as deep as the diameter of the bolt and are run in radially unless otherwise shown on the corner card. The drill is fed into the work by being braced against some stationary work, or else a chain clamp is used.

Building boilers in lots.

When a number of boilers are being built from the same drawings, much work of laying off is saved by piling the sheets one upon the other and drilling through the whole lot at once. The first sheet is punched or drilled and after being carefully looked over to see that everything

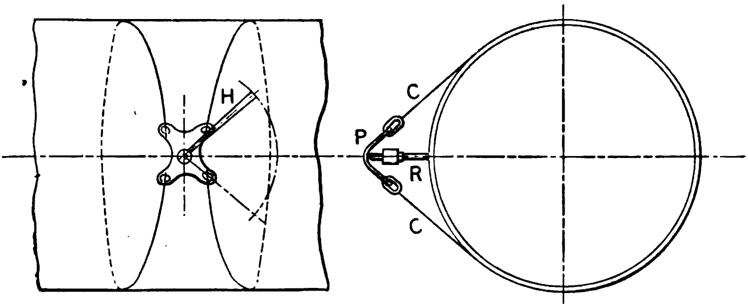


Figure 118 *The Derry-Collard Co.*

Holding drill to the work.

is all right, is used as a gauge to guide the drill for the rest of the sheets. The sheets are placed on trestles or rollers underneath the radial drill. Many of the holes after having been drilled or punched are required to be countersunk. This is the case with most rivets in the water space frame, dome flange, dome cap, etc. Some are countersunk to clear casings or frames, while others are countersunk to give a neat appearance, or, as in the case of a fire box, to prevent the rivet head from burning off. A rose reamer, like that shown in Fig. 117, is best fitted for this work. It gives a much better surface than can be obtained by a flat drill and the countersink will be round instead of being full of corners as would be the case if a flat drill were used.

It should be the aim, in the construction of any boiler, to do as much machine work as possible, although a certain amount of hand work is unavoidable. Fig. 118 illustrates a very convenient arrangement for pushing the drill or reamer into the work. It consists of a piece of boiler plate P with four eyes forged into it, from which chains C, lead all the way around the boiler.

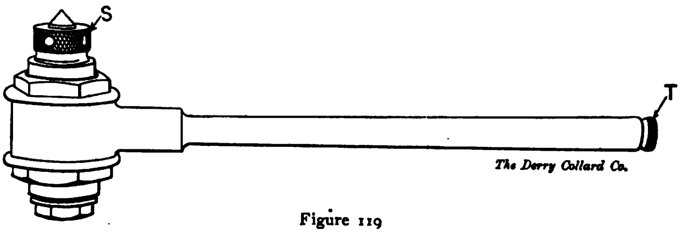


Figure 119

Ratchet drill.

These chains are long enough to encircle the largest boiler, and are provided with a clip so that they can be taken up on one end to suit the proper length of drill. About 90 degrees movement can be obtained with the ratchet handle H, which is plenty large enough for a hand motion.

One of these ratchet drills is seen in Fig. 119. A mill screw S at the top feeds the drill into the work. The ratchet handle can be made to operate right and left by turning the thumb screw T one way or the other. An air drill is much more rapid than any hand drill and wherever these drills can be used to save time they should be employed. The same arrangement that is shown in Fig. 118 applies equally as well to air or other style of drill.

Most wash-out plugs, blow-off cocks, injector-feed connections, etc., are made by brass flanges. As the holes in the boiler are several inches in diameter, they are cut out under the radial drill by an arrangement shown in Fig. 120. The cutter C is square on the outside and at an angle on the inside. It is sharpened by grinding the face.

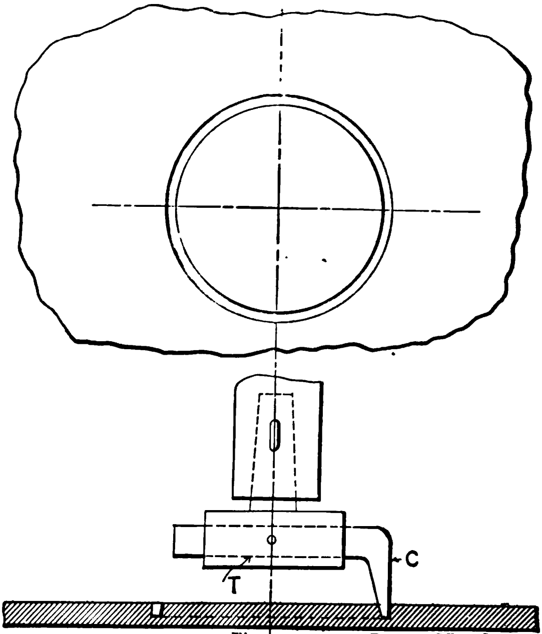


Figure 120

Cutting large holes on radial drill.

The radial arm in this case is lowered so as to support the spindle near the bottom. Where these holes are much larger in diameter, a hole is drilled in the center of the circle and a tit on the lower portion of T projects into this hole and guides the cutter.

The holes in the water space frame are drilled under a multiple spindle drill. These spindles are bunched together, four or six in a group, can be shifted to any position within the limits of the machine, and all of them run through at the same time. A deep pit is provided

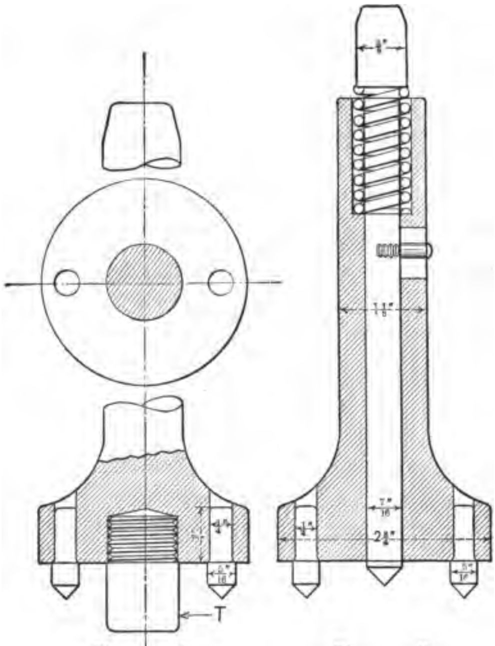


Figure 120A Figure 120B

Two time-saving centering tools.

in front of the machines into which the long water space frames are dropped while they are being drilled. These holes are usually drilled a sixteenth under size and then when the frame is entered into the boiler the holes are reamed out to the proper size. The holes in the brass flanges and different parts of the boiler are scribed off from the holes already punched in the sheet, and drilled under an ordinary drill press, the drill being set to run radially by the eye.

Many of the crow feet and other style of stay-rod ends are drilled by jigs. A machine-steel bushing is used to guide the drill and is much cheaper and answers the purpose just as well as tool steel. The small holes in the outside end of the stay bolts are rapidly drilled by any one of the machines put on the market especially for this purpose. These holes are drilled about one and one-fourth inches deep into the center of the stay bolt.

This center is usually gauged by eye and ordinarily this is near enough to the center. A small center punch arrangement which is illustrated in Fig. 120 B, has recently been described in one of the technical journals. It is intended to center punch the stay bolt exactly in the center. In the first place, before the stay bolt has been put into place, the tit T, Fig. 120 A, is entered into the stay bolt hole, and the punch is hit with a hammer, so as to make two little marks diametrically opposite each other. After the stay bolt has been riveted over, the punch arrangement, Fig. 120 B, is set into these holes and the center punch hit with a hammer, thus locating the center of the stay bolt.

Turning and Boring.

A dome flange like the one on Plate 2 has a great advantage over the style, Plate 5, on account of machining the different parts. They are very quickly put together in the former. In Fig. 121 will be seen one of these flanges. It is made of 1¼-inch steel plate. The

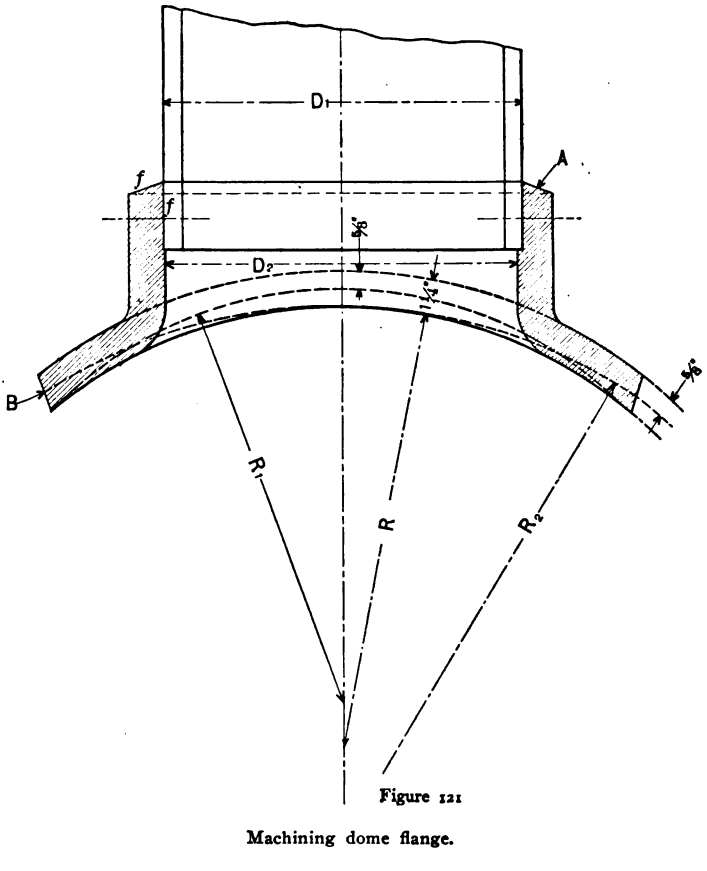


Figure 121

Machining dome flange.

radius R of the die is the same for flanges which are to fit a boiler having a radius R_2, which may be several inches more than the flange radius. R_2 is machined out and the limit of this radius is such that the sheet must not be less than 5/8 of an inch along the lower edge. The limit of the radius R is to give 5/8 at the top portion of the flange. The flange is mounted on the boring mill and is turned out on the inside to a diameter D_1, which is 1/8 of an inch larger than D_2. This is only machined deep enough for the seam. The outer edge of the flange at

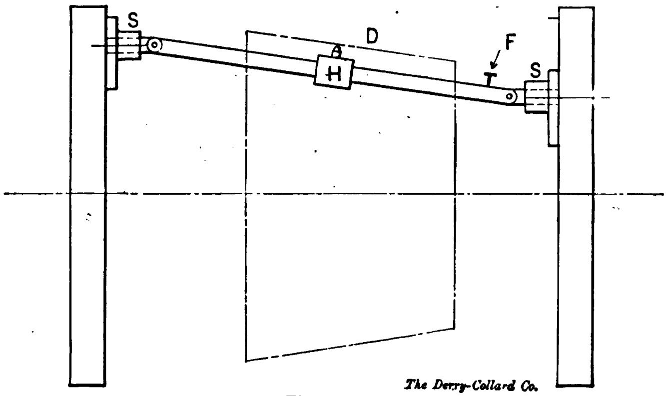


Figure 122

Boring dome flanges in lathe.

A is beveled off for calking. This completes the boring operation of the sheet. Before the sheet has been flanged, however, it will either be put on the lathe or more likely the boring mill, and turned off along the outer edge B. It is a circular sheet when flat.

On some foreign locomotives, and on a few domestic as well, domes are required on the slope sheet. The design has usually been altered so as to obviate the necessity of this construction, but there are times when the builder is required to place a dome in this position. The difficulty in placing a dome on the gusset sheet consists, first, in the expense of new dies; second, in the expense of fitting to the boiler; and third, all the holes harder to

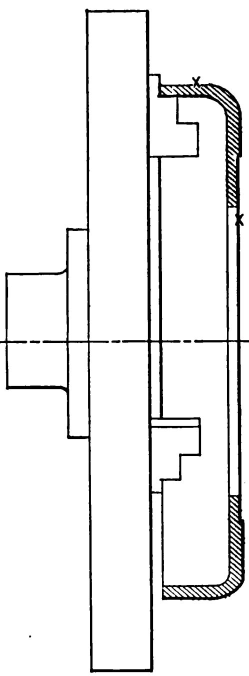


FIGURE 123

Turning dome top.

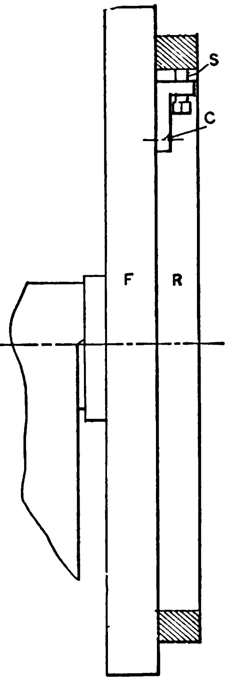


FIGURE 124
The Derry Collard Co.

Smoke box ring.

drill. The slope sheet is approximately conical in shape and the fit between the flange and slope sheet cannot be flanged well enough without afterwards being machined.

This flange can be machined by an arrangement indicated by Fig. 122, which shows the two face plates of a double driving wheel lathe. Joining these two faces is a boring bar which can be adjusted by the hinge joints and sliding pieces S. By shifting them in and out the tool point can be made to travel along the line of the ele-

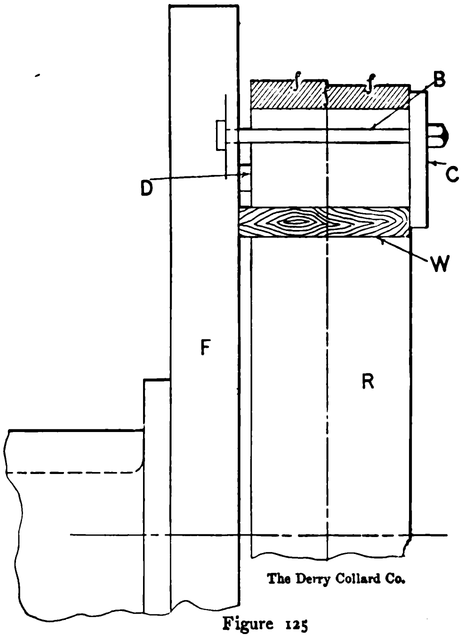


Figure 125

Smoke box ring with two diameters.

ment of the boiler. As these two face plates rotate together, a circle is machined out of the flange at every point along the line. The head H is made to traverse along the bar by a screw driven by the star feed F, which is fitted up by beveled gears. The dome flange is bolted on angle plates, and is supported on the carriage. This operation is expensive although once the machine is set up the time in machining a flange is not much more than double that of planing. The dome cap, Plate 2, is faced off along the outside diameter and faced off on top so as to receive a copper wire gasket between it and the cover plate. This is done either on a lathe or a vertical boring mill.

A smoke box ring is now machined on the outer edge. It is absolutely necessary that the smoke box should be made air tight, otherwise the soot which collects would take fire and we would have a red hot front end. One of these rings is held upon the face plate, Fig. 124, by clamps C. These clamps are provided with set screws S and with them the ring is held rigidly in position, while a light cut is taken off along the outer face. This ring can also be machined on a vertical boring mill. An intermediate ring R, Fig. 125, has two offsets on the diameter. As the boiler is to have the same diameter outside and the sheets vary in thickness, this offset is necessary to match up. The ring is clamped against the face plate of a lathe, with distance pieces D to keep it parallel to the face. Clamps, like that shown in Fig. 124, are used to center the ring and then the ring is held in held in position by B and clamp C. W is a block of wood of sufficient length to clamp nicely. This ring is now turned to the proper diameter. Measurements are made with a calipers and the run is also obtained with the measuring wheel, the two being used as a check against each other. They should come out exactly right. No other turning is done on this ring unless some unusual arrangement of the internal connections requires it.

The front tube sheet, Fig. 126, is in position on the face plate of a vertical boring mill. It is held in position by bolts through the holes which have already been drilled or punched in the sheet. It is now set to run

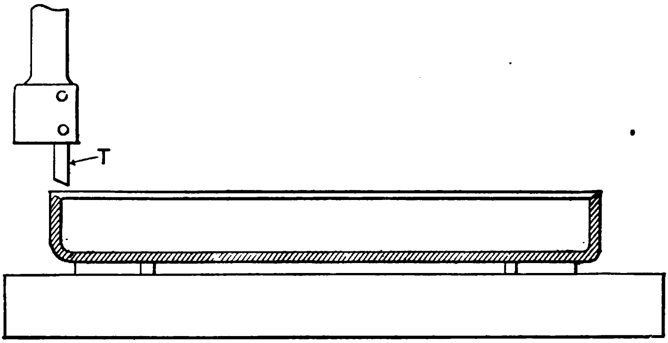


Figure 126

Front tube sheet on vertical boring mill for beveling.

true and the edge is beveled off with the tool R, for calking. As this boring mill would be double-headed, both the tools would be made to cut at the same time.

Tapping and Reaming.

By far the greatest amount of tapping on a locomotive boiler is that which is done for the stay bolts. The threads on the ends of the stay bolts are continuous. That is, if the stay bolt was put in a lathe and the thread cut on one end and then the tool was allowed to run without opening the lead screw nut until it came to the other end, this thread would be continuous. It is evident, therefore, in order to make a good fit that the tapped hole for the ends of this stay bolt should also be continuous. Fig. 127 shows a tap for a continuous thread. The fluted portion A taps the hole while the body of the tap at B makes the thread continuous. On

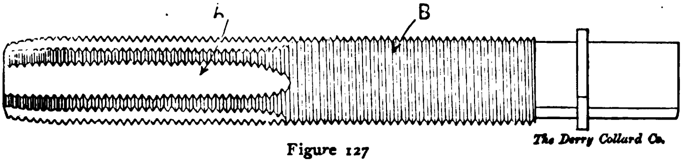


Figure 127

Tap with thread on shank.

long stay bolts this is sometimes lost sight of and their threads are not continuous nor is the thread of the tapped hole in the sheet. The proper way to fit up stay bolts, however, is to have continuous threads.

The holes are sometimes very difficult to tap, as the

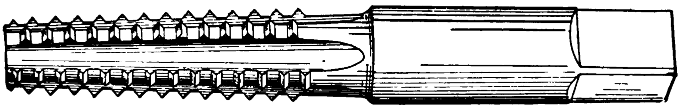


Figure 128

Tap with part of teeth removed.

material is tough and bunches up. Several reasons for this difficulty have been suggested, and various kinds of taps made to overcome it. One of the best schemes, however, and one which seems to answer the purpose very well, can be seen in Fig. 128. It will be noticed that the alternate teeth are removed thus allowing more

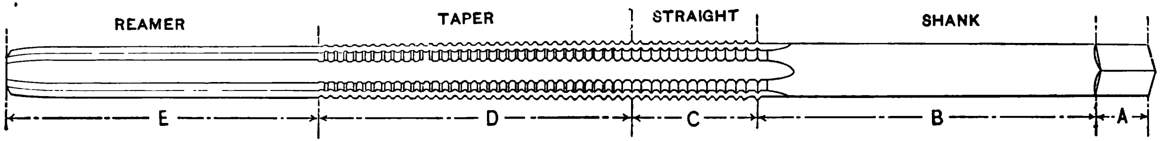
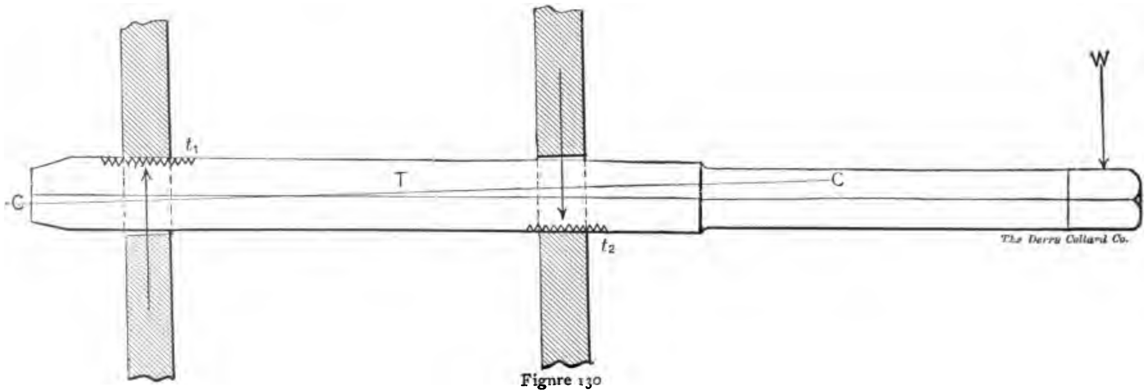


Figure 129

Combined staybolt tap and reamer.



Fignre 130

What too often happens in tapping through both sheets.

room for chips and gives each tooth a better chance to cut. These taps are very largely used by most boiler makers of today.

Most of the stay-bolt holes are tapped by air motors and as little hand work done as possible. Where the work is straight and can readily be brought to the machine they should be tapped by some form of drilling machine. There are several good tapping chucks on the market that are used to great advantage on boiler work. These chucks are provided with adjustable frictions which can be set to pull the tap under ordinary conditions, but which will slip when the tap sticks. This saves many a tap which would otherwise be twisted off, and also saves the annoyance of getting a tap out of a hole after it has broken off. Where the holes are tapped into rings, frames, etc., and where the hole does not extend all the way through, the general practice is to enter the stud into the tapped part 1½ times its diameter.

Fig. 129 illustrates a stay-bolt tap and reamer combined. The first few inches of the reamer is tapered. It then runs nearly straight for a distance E, where the tap begins. The thread is tapered for a distance D, which varies with the length of the tap and then is straight at C for a distance of about three inches. The shank B is turned down a little below the root of the thread, and is long enough to reach through both plates, where a stay bolt is to be placed. These taps are usually driven by air motors and are run straight through the first sheet and then into the second; having run through both sheets, it is allowed to drop into the inside of the boiler. This operation is repeated for each hole.

Threads for wash-out plugs, corner plugs, injectors, check flanges, etc., are nearly all tapped by hand. The taps being large and requiring an enormous pull to turn them, a long wrench is used and power applied by one or two men at the end. The tapers vary with the different builders as also do the number of threads. Twelve threads to the inch, however, is common for plugs and flanges and is almost always used for stay bolts.

The reamers that are used for opening up the rivet holes are very long and only slightly tapered. The continuous flutes are interrupted by a thread-like cut which breaks the chips into short pieces, and tends to draw the reamer into the sheet. Other reamers are made where the flutes are spiral, the direction of the spiral being arranged so as to pull the reamer into the work.

Fig. 130 shows a too frequent occurence in tap holes for stay bolts. T shows the tap and t_1 and t_2 shows the inside and outside boiler plate. W is the weight of the motor. As these taps have keen edges, this weight is sufficient to make the tap cut down on the outside sheet and up on the inside sheet, thus cutting away the metal at these points, so as to give a full thread here and only a half a thread on the opposite side. The remedy, of course, is to hold the motors right, but as they are heavy, workmen will allow them to drop and the result is that some holes do not pass the inspector. The little riveting up that a stay bolt gets on the outside of the sheet does very little good in adding strength, and therefore a full thread alone should be depended upon.

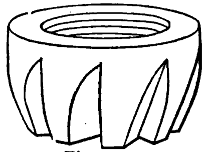


Figure 131
The Derry Collard Co.
Rose reamer for sheets.

The joints for the steam pipe, for the dry pipe connection to the throttle, the injectors, steam valves, throttle lever stuffing box connection, etc., are now almost entirely made by ball joints. The sheets are reamed out by rose reamers, similar to Fig. 131. Sometimes they are solid and at others as shown here. In any case they are spherical in form and must be applied to the sheet under pressure, sufficient only to make the reamer take hold. The part that fits into this ball joint is machined spherical to suit the gauges and then the parts are ground together with powdered emery.

Planing, Milling, Etc.

All water space frames are now machined inside and out. In addition to this, they may have pads front and back and finished spots for cross ties on the sides. A plain, flat water space frame is shown in Fig. 132. It is laid off, then lined up on the machine, and planed along the outside edge at A. It is then thrown around and planed along the edge at B. This frame is then removed and the corners milled and slotted, when it is again brought back and the remaining material planed off and machined carefully to the exact figures. The amount of finish may vary from nothing up to half an inch or more.

Lugs for supporting the boiler are frequently required to be machined to fit certain connections on the boiler. These connections are usually arranged so that the planing need not be to any exact figure, the surface alone being trued up and the matching arranged for in some other part. These lugs should be avoided as much as possible in the design, especially in boilers which are subject to foreign shipment. They are frequently bent and sometimes broken off, which makes an expensive repair. A very good way of supporting the boiler is to bolt an angle iron underneath the water space frame and bolt the support to it.

Fig. 133 represents a dome base which is being machined out to the proper radius of the boiler. It is

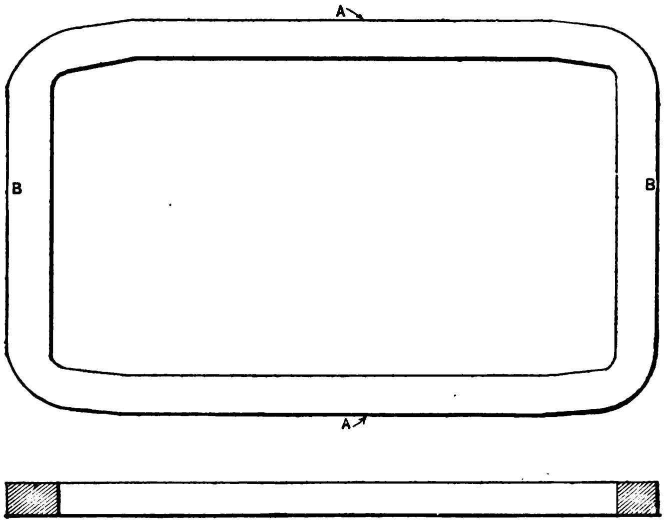
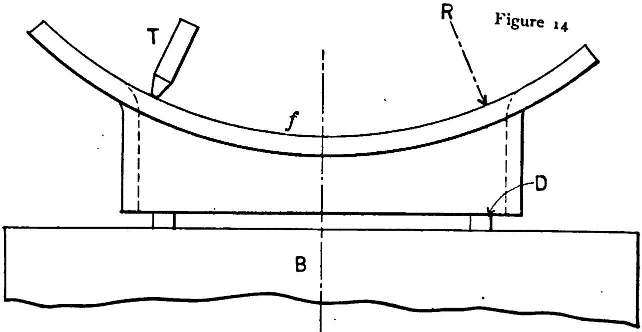


Figure 132

Plain water space frame.

mounted and clamped down rigidly upon the bed of the planing machine. The holes having been drilled in the flange, it is readily clamped to the bed of the machine by using these holes. D is a distance block which is placed underneath the flange. The flange is marked front and back with a center punch mark. A pointer is placed on the tool post and the bed run back and forth, the flange being bumped around so that its center line will be parallel with the center of the bed. It is now clamped in position. T is the planer tool which is rigged upon a rotary head. The radius R of the point of the tool is made to suit the boiler. A cut is now started beginning at one end. The rotary head of the planing machine is provided with a feed mechanism to move the tool radially across the flange.

Heavy vertical milling machines are gradually being introduced by nearly all the locomotive shops. These machines are almost universally used for milling the corners of water space frames. D, Fig. 134, is the diameter of one of these milling cutters. The sheet is



Machining dome base to fit boiler.

clamped upon the table of the vertical milling machine and the table is run back and forth so as to mill the line A, the radius of the cutter being the same as the radius of the inside corner. The cutter is now run down along the line B and a cut is taken off of sufficient length to start or stop the planer tool as the case may be. The metal at S is slotted out after the milling process is complete. The frame is now shifted on the bed of the milling machine and the center C of the outside corner is made to coincide with the center line of the table. This can be done in several ways, one of which is to put a block of wood at C and find the center on it, and then having a conical shaped tool to put in the spindle. The spindle is lowered and the table shifted until the center

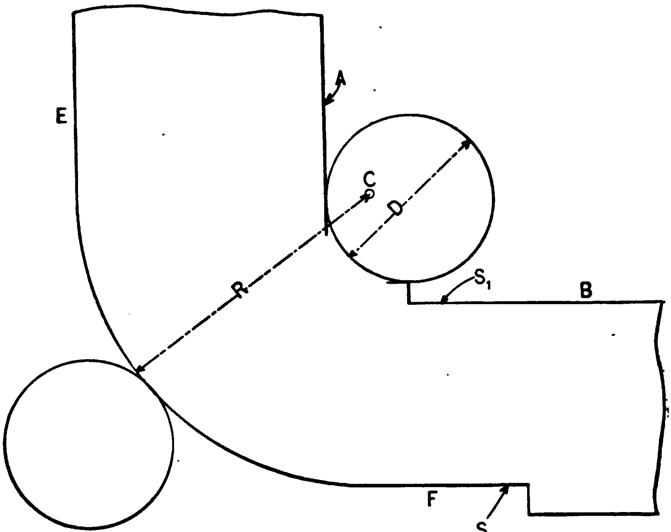


Figure 134

Milling water space frame.

stands exactly over C. Or a scriber is attached to the spindle, and is set to the radius R of the frame. It is then adjusted so that the scriber coincides with the line E. The spindle is then turned through 45 degrees and

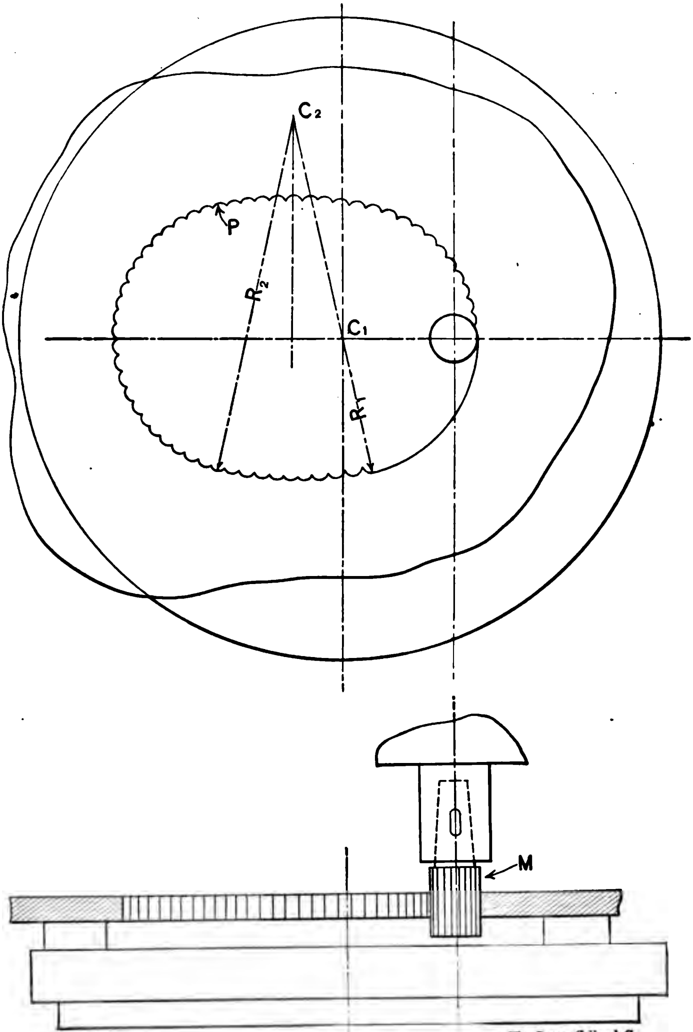


Figure 135

Milling out a punched hole.

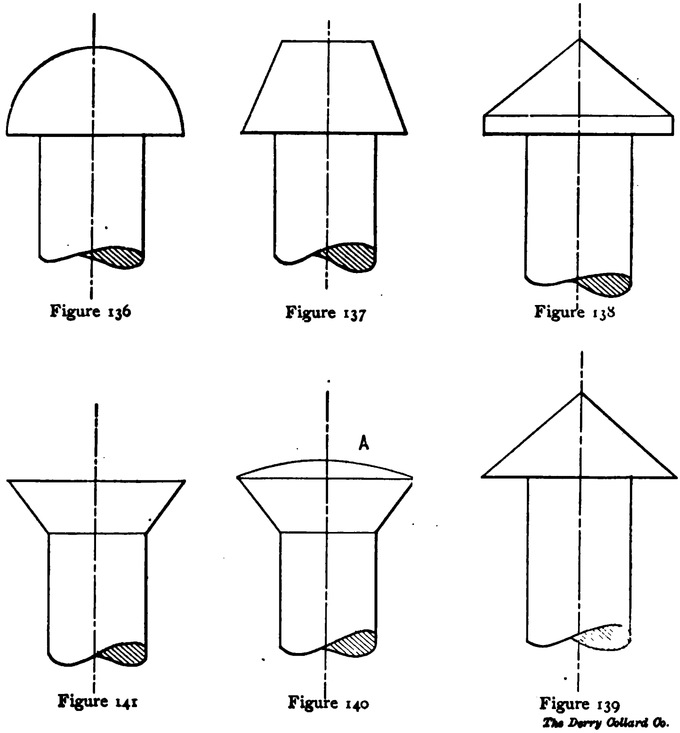
the frame shifted at right angles to the previous direction, until the scriber coincides with F. The table having been set central with the spindle in the first place, the center of the frame must of course be over the center of the table. The table is now shifted and the milling cutter fed into the outside of the frame until it comes to the line of the corner. The table is now fed around and the corner will be milled off to the radius R. After 90 degrees has been made the cutter is allowed to run along the line F and then along the line E to meet the original planing. The metal at S_2 will be removed by a slotting machine.

Fig. 135 shows how the rough surface of a punched hole is milled smooth. This figure represents the hole that is put into a dome flange like that shown in Fig. 133, before the sheet is flanged. It will be remembered that it must be elliptical and must be machined smooth before flanging. P represents the burr left after punching, R_1 and R_2 are the approximate radii of the ellipse. The center C is first set over the center of the table which is shifted and the milling cutter M is allowed to cut away the metal as indicated. This is also done on the other side of the sheet, which is now shifted and C_2 placed over the center of the table. The table is shifted and the cutter allowed to run along the part corresponding with R_2. This process is repeated on the other side of the plate. Thus a smooth machined hole all around the periphery of this ellipse is obtained.

Since so many failures have been traced to staying and to badly fitted up bolts, the best material only should be used for this purpose and the best workmanship placed upon it. In almost every case, all crown bar and stay bolts are turned steel bolts, which are made to fit reamed holes. The bolts have nuts and are provided with cotter pins outside the nuts. Nearly all stay bolts are made in bolt machines. They are of the best Norway or Swedish iron or its equivalent and upset at the ends before being threaded. Short stay bolts are threaded the whole length and in other cases the thread is cut out for the central part of the stay bolt. The bolt with the upset end is much more durable.

Riveting.

A boiler rivet has become such an ordinary, every day affair, that we scarcely realize the important role it plays in the construction of the boiler. Much of course depends upon the quality of the material used, and upon the manner in which it is driven. A rivet driven under pressure or what is generally called a machine driven rivet, is far superior to a rivet driven in any other way. There is less liability of having loose rivets than in the case with hand driven rivets or rivets driven by snap air riveters. Nearly all rivets on locomotive boilers are made button head like Fig. 136 unless otherwise specified, as this is the cheapest style of rivet to drive by machine. When rivets are driven by hand, the head for holding on is flat so as not to batter it up. The remainder of the head flares out like Fig. 137. Sometimes a rivet head like Fig. 138 is specified and occasionally it takes the form of a radius instead of a straight line, *i. e.*, somewhat conical in shape, but instead of having straight lines, the lines are curved. This gives a heavier head, although rather more difficult to make than any other style. Fig. 139 illustrates a conical head rivet which is a style invariably



Forms of rivet heads.

obtained by hand riveting. All fire box seams inside and outside are now countersunk and also all rivet heads which interfere with other parts or must be countersunk for clearance or for appearance. This style of rivet head is seen in Fig. 140. It is curved at A about as shown, which makes the head stronger. Many people countersink all mud ring rivets, using this style of head.

Where it is absolutely necessary to have the rivet heads perfectly flush, they are made like Fig. 141. As it is almost impossible to have just enough material to

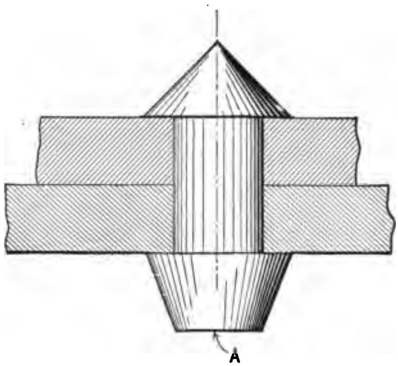


Figure 142

A hand-driven rivet.

fill up the rivet holes, one or the other side of these heads is apt to come a little full, and therefore the rivet must be chipped off flush. This is usually so noted on the drawings.

Wherever it is possible to drive a rivet by machine, it should be done, but there are cases where it cannot be done profitably, as for instance on the back head. This head is entered into the side and crown sheets, and then these rivets and also those in the fire door are hand driven. They are entered into the sheet from the inside, and while the rivet is being held at A the head is hammered down as seen in Fig. 142.

Various Operations on the Riveting Machine.

We will now consider the method of hanging a boiler over the riveter stake of a large hydraulic riveting machine. A single course of a locomotive boiler is very readily picked up and dropped down over a riveter stake, but a large boiler like Fig. 143 is not so easily handled.

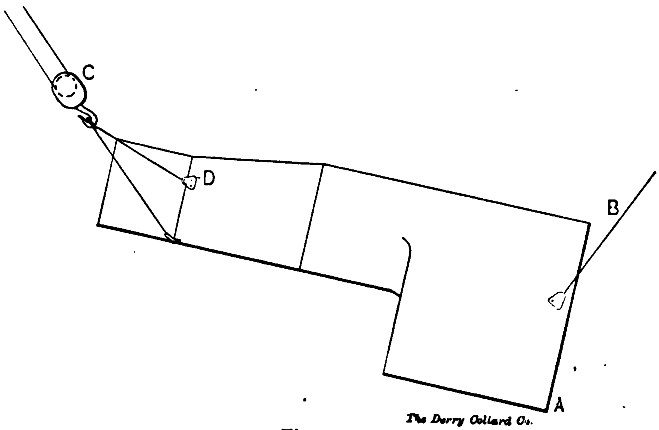


Figure 143

Holding boiler over riveting stake.

On the floor, this boiler rests in the same position as it does on the engine. The block C of the hoist is hooked into the three chain link as indicated. Now it would be

In the first place the sharp edges at A would cut into the floor and tear everything as it went along. Secondly, the boiler plate being flexible, the boiler would be apt to fall over on its side and bump into something else; and thirdly, after the boiler had been nearly raised from the floor, it would roll around and endanger everything about it.

For this reason a pulley block is attached at B, the boiler is raised off the floor and is thus suspended in the

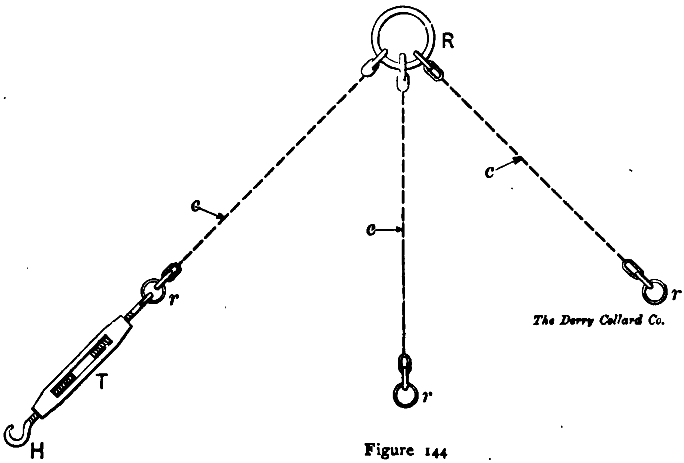


Figure 144

A good rig for supporting boiler.

air. C is now raised while B follows, always keeping the boiler off the floor, until all the weight is finally taken by C. Where there are several riveting machines, instead of using a pulley block at B, one of the other hoists can be used instead.

The arrangement commonly used for supporting the boiler is shown in Fig. 144. R is the ring which engages with the crane hook. T is the turn buckle, C are chains and H engages with some part of the boiler. The

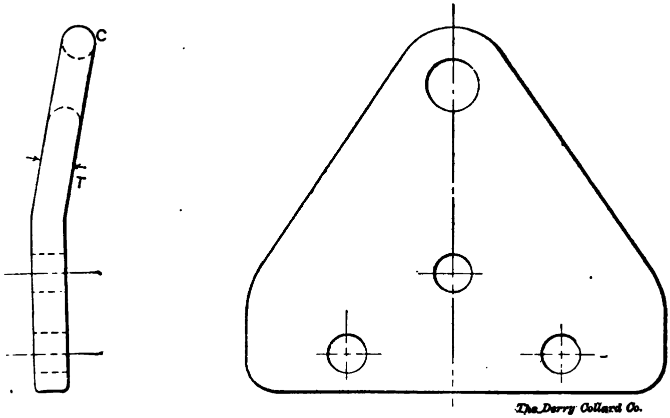
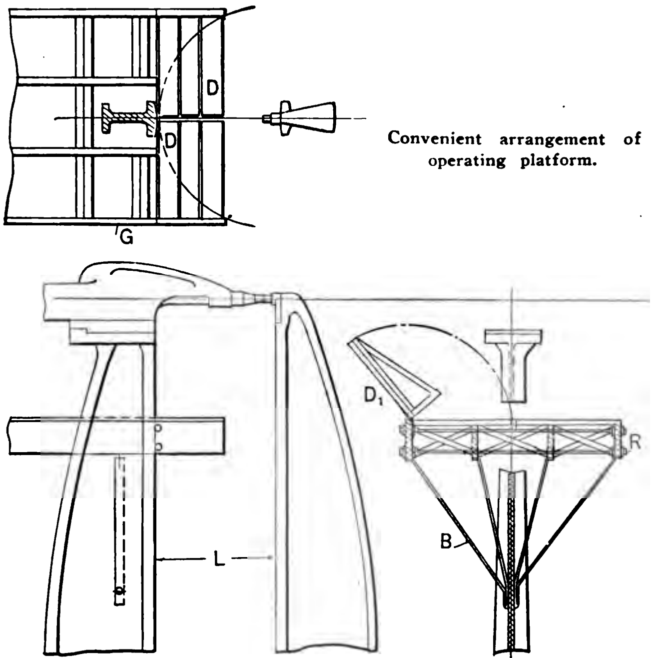


Figure 145
Plates for holding boiler.

object of the turn buckle is to level the boiler, which is usually important.

Boiler plates about ⅝ of an inch thick at T, Fig. 145, have several holes punched into them and are bolted to the boiler at D, Fig. 143, to support it. Two or three ⅞ or one-inch bolts in each are sufficient. This boiler plate is slightly bent so as to take the chain at C. Three of these plates are used on each boiler. They are attached as indicated in Fig. 143 for the reason that a large boiler would be too long to go over the stake if the chain was not coupled very short. Of course if there is plenty of overhead room some other connection would be satisfactory.

The platform on a large boiler riveter is very large and the gap at L being great, it is sometimes difficult for the operator to get near enough to the dies. This inconvenience is entirely overcome by an arrangement of the platform shown in Fig. 146. D are trap doors which



Convenient arrangement of operating platform.

Figure 146

The Derry Collard Co.

are hinged upon a girder G. D represents one of these trap doors being thrown back out of place.

Where one is riveting around the bottom center of the throat sheet, the legs of the water space frame stick in around this platform, therefore these doors are all arranged so that they can be thrown back out of place. Under ordinary conditions they are in place as indicated

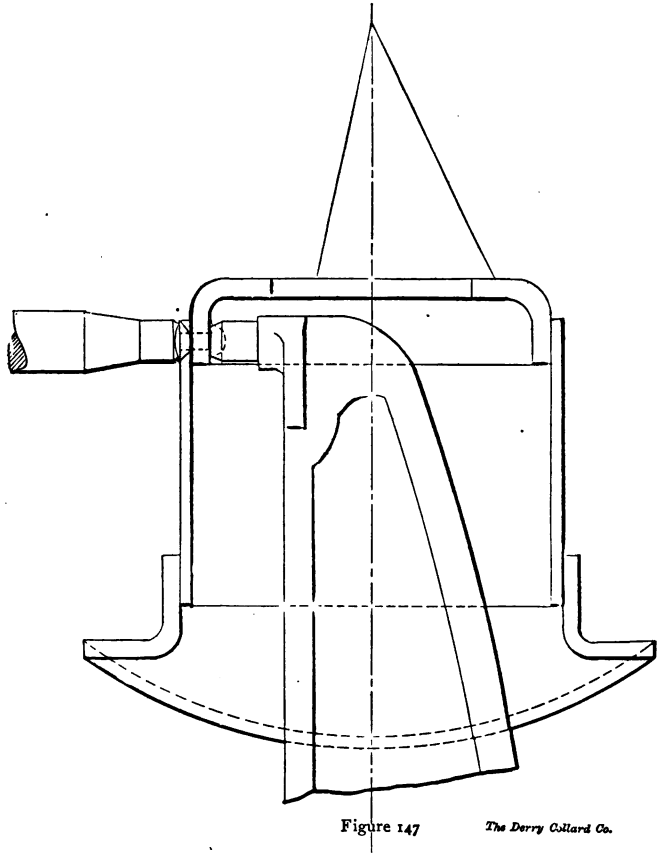


Figure 147 The Derry Collard Co.

Riveting a dome.

by this figure. R are wrought iron bolts threaded at each end and having nuts on each side of the girder. By means of these rods any sag in the doors can be taken up by adjusting these nuts.

The riveter stake and also the frame deflect under the load, the amount of this deflection depending upon the size and capacity of the machine. It is apt to be as much as 5/8 of an inch for either the stake or frame. For this reason the platform should not be fastened to the stake, but to a permanent structure. A wrought iron bracket B four of five feet long should be arranged to support the riveter end of the platform, while the rear

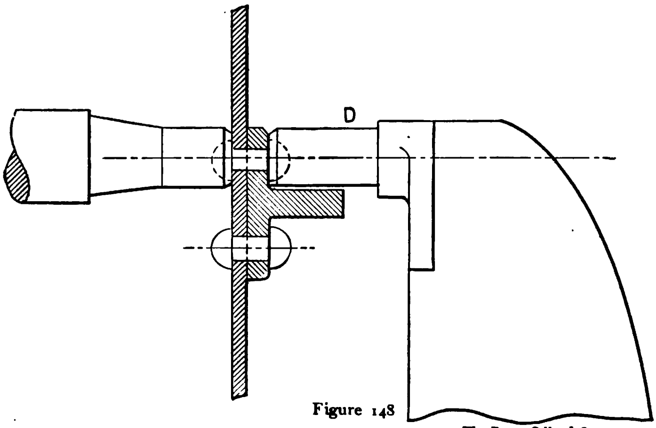


Figure 148

The Derry-Collard Co.

Riveting crown bars.

end can be attached in some way to the building itself. The floor being cut out around the rivet frame, the deflection will not interfere with the platform.

A simple case for riveting in seen in Fig. 147, showing a dome. This work can be done upon a short riveting machine. The dome is supported by three chains C which are attached to the bolt holes in the dome cap.

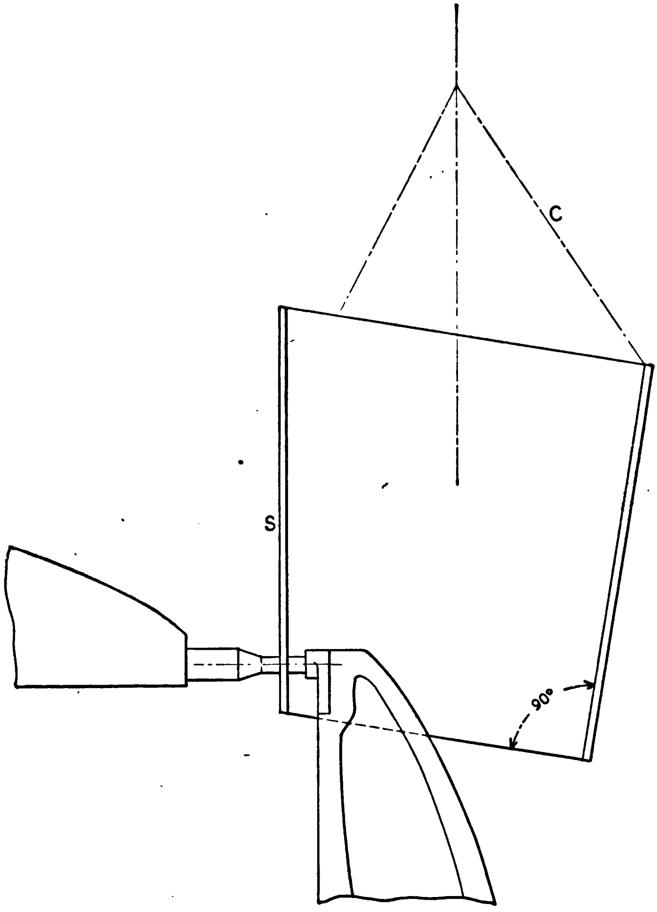


Figure 149

Riveting slope sheet of boiler.

Dry pipe ring.

The plate and flange are held in position by a few bolts, enough to draw the sheet firmly together at the joint. The rivets are entered into the sheet and countersunk on the outside. They are driven one after the other, the

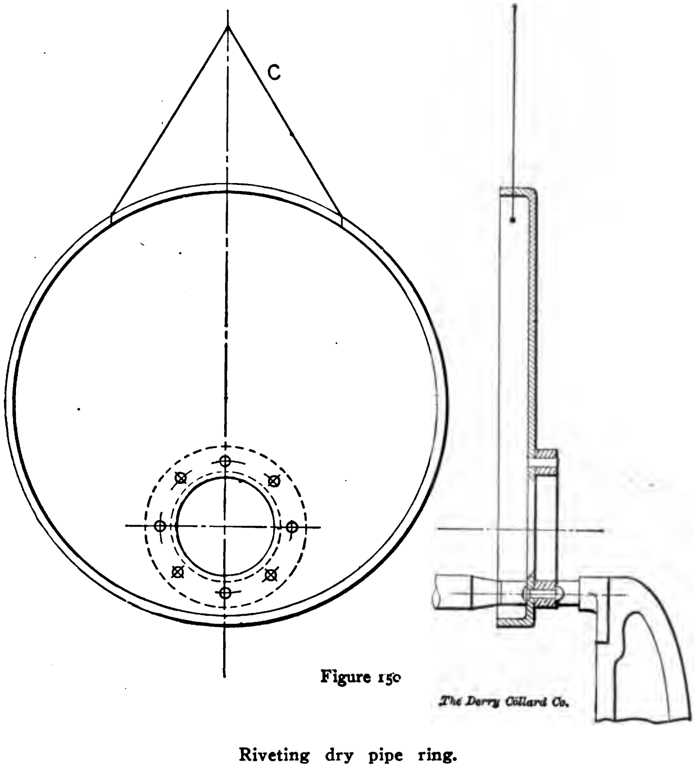


Figure 150

Riveting dry pipe ring.

nuts removed from the bolts, the bolts knocked out of place and dropped down on the inside. The process is continued until the rivets are complete in one row. The crane is then made to raise the dome up to the line of the second row of rivets and these are driven in a similar way.

The crown bars of the locomotive boiler are frequently made of T iron sections, Fig. 148. The die D is lengthened out so as to clear the T iron and is also cut away on the bottom for clearance. Unless the rivet head

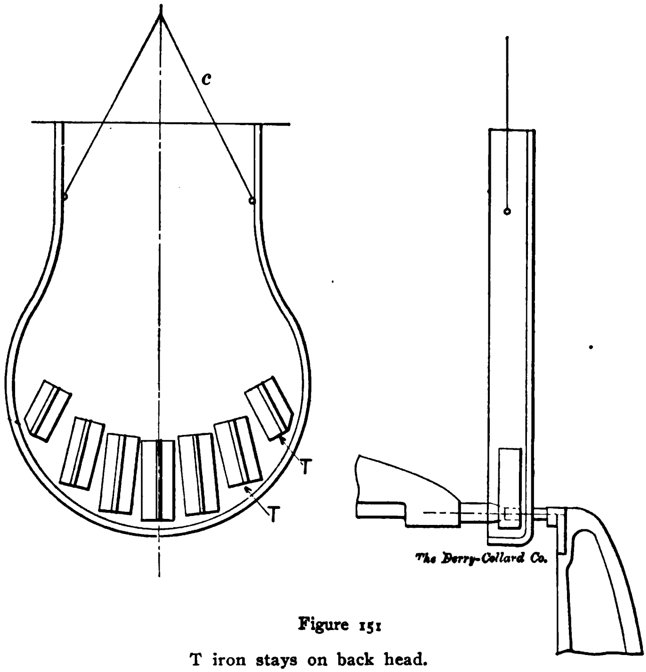


Figure 151

T iron stays on back head.

is on the outside or interferes with some other part of the boiler, they will be driven with button head rivets inside and outside as in this illustration.

Fig. 149 shows a slope sheet of a boiler, the seam being on the top center. If this boiler has a great deal of slope, it would interfere with the stake in riveting the longitudinal seam. For this reason the chain C is coupled up in such a manner as to throw the slope part of the sheet plumb. The boiler is raised and lowered to suit the holes and the rivets are driven in this seam.

The method of riveting the dry pipe ring to the front tube sheet is illustrated in Fig. 150. The sheet is supported by two chains C, from the crane hook of the riveting machine. These rivets are usually button head on the inside, but on the outside they have countersunk heads. The flange of the dry-pipe elbow comes so close to the sheet, that the heads must be countersunk to clear. Once the rivet is driven as shown, the crane hook is lowered to the level of the next rivet and the bridge of the crane is traversed so as to bring the hole in line with the dies. This process is repeated for the next rivet and so on.

A back head of a boiler is supported from a crane hook in Fig. 151. The T irons used in staying the back head are shown at T. All the holes in the boiler and these T irons have been punched or drilled, and the T irons held in place with several bolts. As the rivets are driven, these bolts are taken out and all the T irons are riveted into place.

After the dome, the front tube sheet, the back, etc., have been riveted up complete, the various parts are attached to the boiler by bolts. Frequently a half dozen or more washers are put in to make up for the various lengths of bolts used. Each one of these washers being more or less elastic, the plate is held more firmly together than it would be if plain bolts without washers were employed. As the pressure is brought on to the rivets, the space between the plates becomes very small, and as the rivets follow on around the boiler, the elasticity in the washers will take up the space left between the plates as the rivets come along.

In some shops the dome is riveted on the boiler by machine, while other places which are not fitted up especially for this work, must content themselves with hand driven rivets.

All the rivets in the longitudinal and transverse seams of the boiler proper are riveted on the machine. Where a long stake riveting machine is not to be obtained, the circumferential seam in front of the throat sheet is riveted up by hand. Sometimes the boiler is too long to reach all the rivets when the boiler is in one piece. The rivets are then driven in each of these two parts of the boiler by machine and then the sheets entered into each other and the remainder driven by hand.

The fire box, the mud ring, and the back head, are put in place after all the other rivets have been put in by the riveting machine. The rivets in one end of the fire box and some of those in the other end, can be put in on the machine while the remainder must be driven by hand. After the boiler has been partly riveted, the scarfed seam and seams that overlap each other, must be heated up and pounded back into shape so as to make the seam as tight as possible. After all these seams have been gone over and hammered down neatly into place, the holes are reamed out true, and the remainder of the rivets driven. After the fire box has been entered into place, and the mud ring has been put in position the mud ring rivets are also ready to be driven.

Fig. 152 shows an air riveting machine for water space rivets. The boiler is rolled on its back and the riveting machine supported from a crane hook. Hydraulic machines are also used, although not so extensively as the compressed air riveter here illustrated.

The pressure tanks on air engines are usually made to stand high pressures. The ends are flanged to the

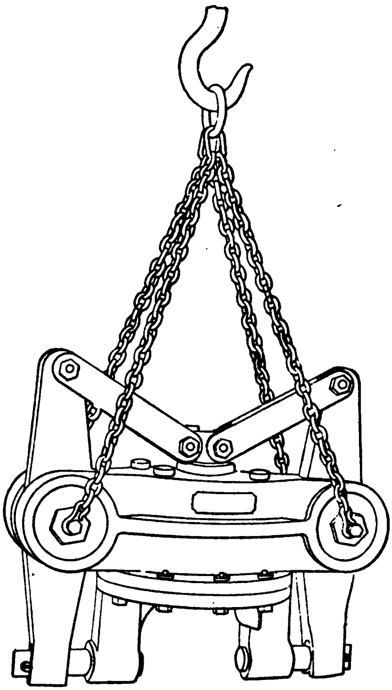


Figure 152

Air riveting machine.

radius of the boiler and entered into place as seen in Fig. 153. One end is entered and riveted up on the machine provided that the boiler is large enough to slip over the stake. The other end of the boiler is flared out like the first only it has a hand hole H provided in such a manner that one can place the hot rivets into the hole

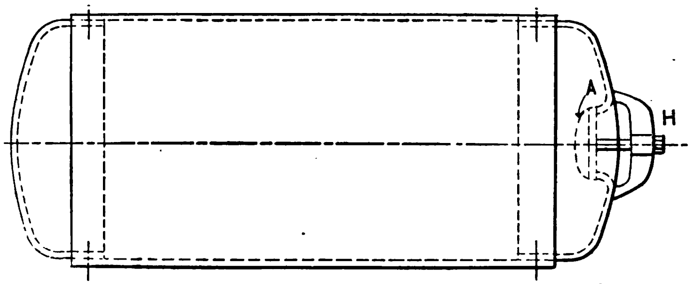


Figure 153

High pressure tank.

from the inside. The hand hole is then covered up with the plate A with a gasket between it and the boiler, to make the seam air tight.

The Riveting Machine.

Nearly all riveting machines at the present time are operated by hydraulic pressure. This pressure varies from one thousand to two thousand pounds pressure per square inch. The diameters of the cylinders are such that the required pressure is obtained upon the rivet. Fig. 154 represents a cross section, through a pair of dies and two plates. It will be seen that the dies do not touch the plate and it should be a rule never to allow the die to come in contact with the plate, but to take the entire pressure on the rivet head. This figure represents what is altogther too common with old riveting machines.

A shows the difference between the center line of the two dies. This is brought about by the shifting of

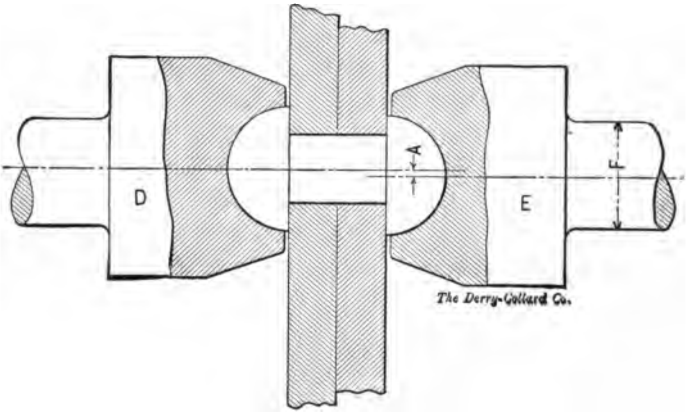


Figure 154

Riveting dies out of line.

the stake on the frame. It can be remedied in a number of ways, but should never be allowed to be much out of line as the head of the rivet would not be central with the body. This eccentricity of the head is a very bad thing when the rivet is in direct tension, as the stress in this case is much greater on one side of the rivet than on the other.

Dies are always made of tool steel and should be kept in good shape. The number of rivets that such a die can drive, depends upon the steel, the pressure, the kind of rivets and so on, and may vary anywhere from a few hundred to several thousand. As soon as the die gets out of shape, and always before it hits the sheet, it should be sent back to the tool room and reshaped.

Fig. 155 represents a flat lathe tool for shaping up a die for a button head rivet. The shape of the rivet heads is sometimes dependent upon what certain engineers consider correct and frequently the rivet head is specified to the builder. In this case the dies would all be shaped up by some form of flat drill in the lathe.

The head of the the rivet before being driven need not be and in fact very rarely is the shape of the finished rivet head which is required. Indeed many use rivet heads like Fig. 137 for all purposes where a button or other outside head is required. It is believed that the upsetting action, which is necessary to bring such a head into a spherical form, improves the strength of the rivet.

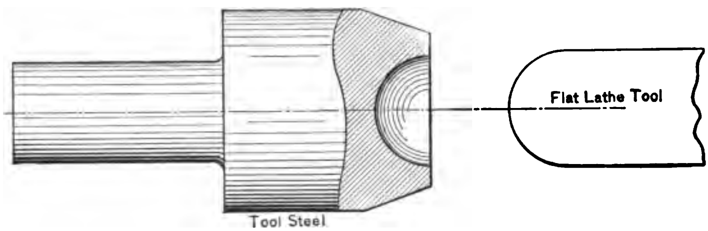


Figure 155
Making a die for button head rivet.

The rivets are almost universally made of wrought iron. The heads of steel ones for some reason seem to have a tendency to snap off after the rivet is driven.

Various methods are used for heating the rivets. Several of the large locomotive builders in this country use egg or nut coal with the air blast, while others, especially in the far West, use oil almost entirely. The coal fire is usually arranged on the riveter platform quite near the machine and sometimes is arranged with a pipe

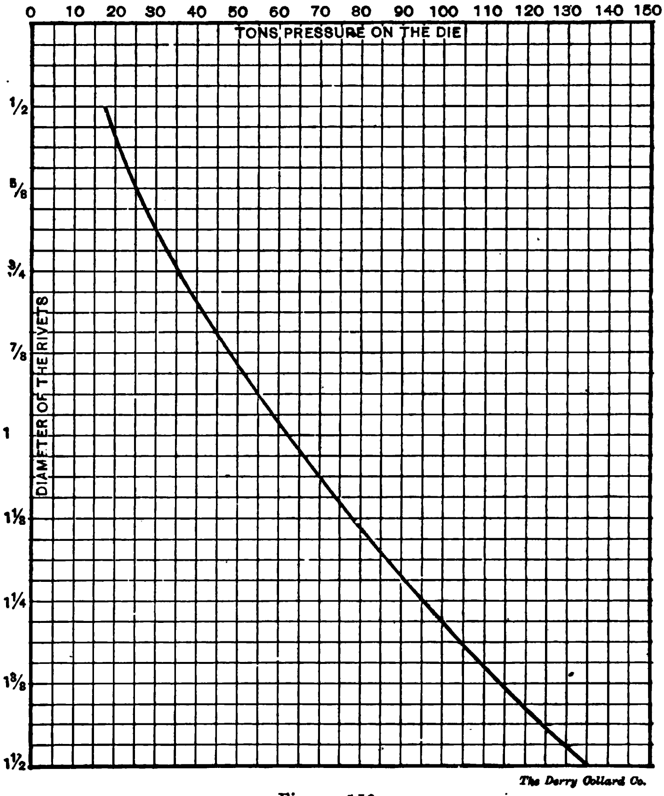


Figure 156

Pressure required for rivets. See page 188.

for carrying off the gases. Too frequently, however, no provision for taking care of the gases is provided for. The coal fire does not give as uniformly heated a rivet as does an oil fire. When button head rivets are used and when these rivets are driven by button head dies, it is not so important that the head be heated as hot as the end, and therefore the kind of fire to be used depends very largely upon the condition under which the rivets are driven.

The number of rivets that can be put in with one of these machines may reach as high as eight or nine hundred a day, but there is one thing that should not be forgotten in rapid riveting. The metal of a rivet flows freely at a red heat, but only attains its greatest strength when the rivet is cool. As the heat of the rivet cannot be absorbed by the dies and sheet in an instant, four or five seconds is sometimes necessary before the rivet cools off sufficiently to hold the sheet in place. The rivet should therefore be held four or five seconds before it is released. Wherever speed is gained, it should not be done at a sacrifice of this kind. The dies of course become hot and must be cooled by frequent application of water.

The pressure required to drive various size rivets is dependent on the diameter of the rivet. Most hydraulic machines are arranged for three pressures, and give pressures at the dies according to the size and capacity of the machine about as follows:

1st	— 25 —	50 —	75	Tons
2nd	— 33 —	67 —	100	"
3rd	— 41 —	83 —	125	"
4th	— 50 —	100 —	150	"

Machines of the latter capacity have recently been furnished and are intended for very large rivets.

Fig. 156 shows the pressure which is required for the rivets. The curve is plotted for a fibre stress upon the area of the head of the rivet of sixty thousand pounds to the square inch. It will be seen from this figure that the pressures of the common size rivets are as follows:

½	Inch	rivets	require	18	Tons
⅝	"	"	"	26	"
¾	"	"	"	36	"
⅞	"	"	"	48	"
1	"	"	"	63	"
1¼	"	"	"	95	"
1⅜	"	"	"	114	"
1½	"	"	"	135	"

Fig. 157 shows a riveting machine which can be seen in a number of locomotive shops. This machine is flush

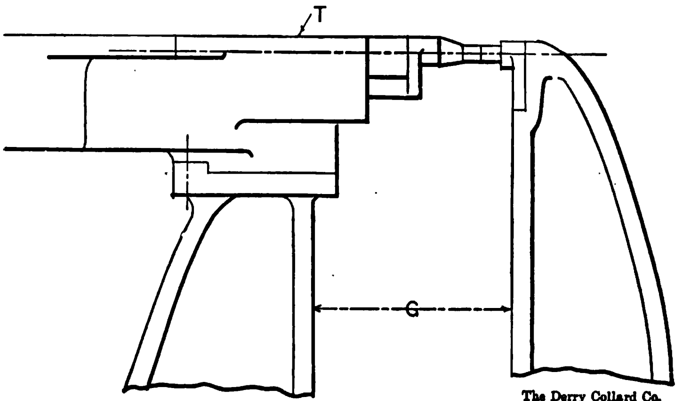


Figure 157

An ordinary riveter for general work.

at T and the gap G is from thirty-six to forty-eight inches. This machine admits of a good part of the work of the locomotive boiler but does not lend itself to getting in corners such as close places around a throat sheet, dome, etc. For this reason we find in some shops a more improved type of machine shown in Fig. 158. This machine is also flush at T but has a long forged horn H extending out from the top slide of the cylinder. With this machine one is able to get into many small places which would be impossible on the machine shown in Fig.

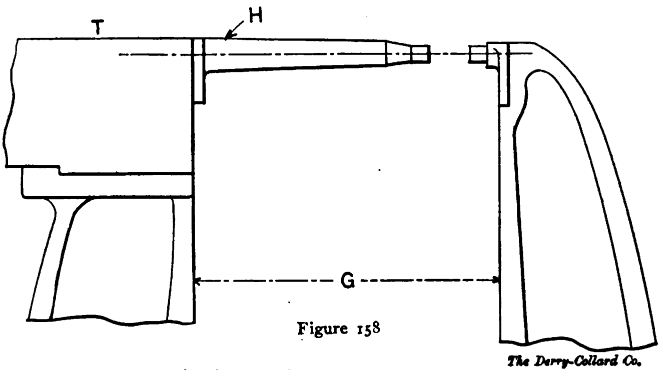


Figure 158

An improved type with long horn.

157. With it every rivet joining the dome flange to the boiler can be reached and also the rivets in the throat seam. Sometimes in order to reach every rivet in the seam it is necessary to have a special die, in order to clear the welt strip, throat sheet, etc.

When a boiler is suspended on the hook of the crane the fire box hangs down, and in riveting up the throat sheet as well as in driving all the rivets near the throat sheet and along the bottom, it is necessary to have a cylinder flush underneath. Fig. 159 shows such a cylinder. This type was invented a number of years ago by S. M. Vauclain, of Philadelphia, and has since come into very general use. It is known as the Vauclain or flush bottom cylinder. T is made as small as possible in order to be able to reach all the rivets in the throat sheet. At the same time A is faced off in order to get in close to the flange. G on twelve-foot riveters and over is now frequently made fifty-four inches, which is wide enough to take in almost any kind of a boiler now being built.

Hand Riveting.

The amount of hand work to be done on a locomotive boiler is much greater than it should be. Perhaps in the near future much which we now consider absolutely necessary to be done by hand, will then be done by

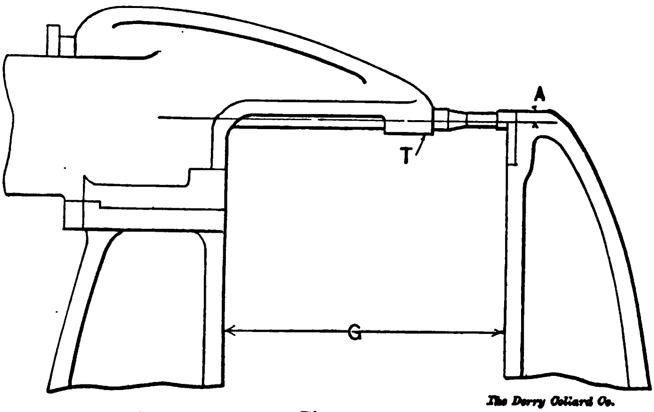


Figure 159

Vauclain flush button riveter.

machine. There are hundreds of rivets on every boiler and most of them in awkward positions which must be put in by hand.

Fig. 160 illustrates a heavy holding on hammer and hook. The rivet head is like Fig. 137. It is thrown into the boiler, entered into place and the hammer H is brought up into place. The hook T attached to some punch hole or to a strap or some other convenient place is gaged to suit this position. T is made as small as possible so as to get a long lever. The holder-on throws his weight on at M, the head R is then pounded

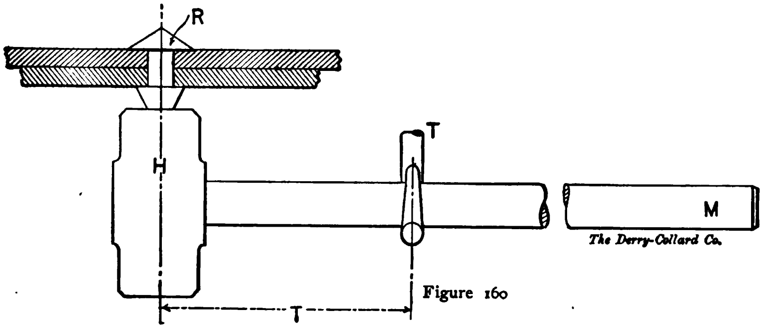


Figure 160

A hand "holder-on."

down by one or more riveters. After the head has been hammered into its proper shape, a forming tool, Fig. 161, is used to make it smooth.

The fire door shown on Plate 2 and all others of this style are hand riveted. The rivet is entered from the inside of the boiler and the end to be riveted is hammered radially toward the center of the fire door opening. While it is thus held in position, the head is riveted over by two men, one striking from the outside and the other from the inside of the fire box.

The rivet is held in place by an arrangement shown in Fig. 162. The main part D is made of wrought iron and is eight or nine inches in diameter. The width T is made 1½ to 1¾ inches. The handle H is

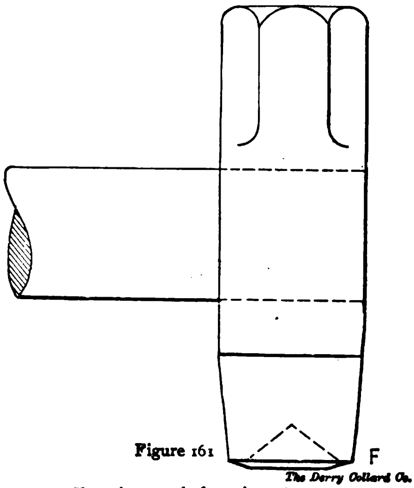


Figure 161

Forming tool for rivet head.

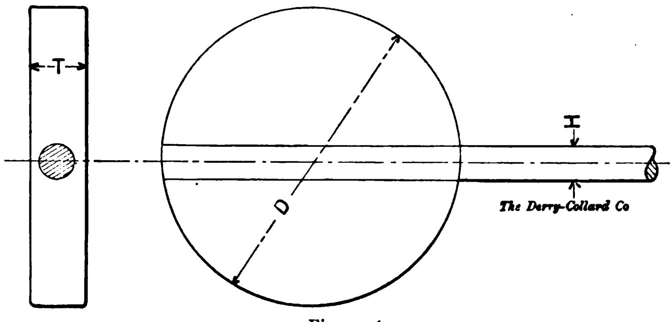


Figure 162

Holder-on for fire-door riveting.

made of wrought iron and is 1⅛ to 1⅜ inches in diameter. This handle is bent to suit the boiler, and it is entered between the back head and the back fire box sheet. A fulcrum is arranged in such a way as to bring the head D upon the rivet in order to hold it firmly in

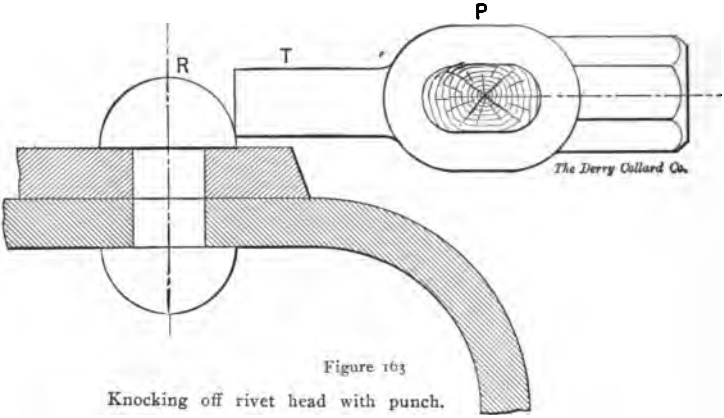


Figure 163
Knocking off rivet head with punch.

place. As this head is round it readily lends itself to holding on the rivets at the different positions. The fulcrum consists of a strap of iron which is hooked up to different lengths and is attached by means of bolts into the holes for the stay bolts.

Whether rivets are driven by hand, or by machine, unless the sheets are well bolted together before riveting, there are apt to be some loose rivets. When these rivets are detected, which may be frequent or only on rare occasions, they must be taken out and new rivets put in their place. It is not an uncommon thing to find loose rivets in the water space frame and in the circumferential seams. The rivets in the water space frame being very long, the amount of material of the rivet is not exactly equal to the rivet hole, and therefore we have a loose rivet. In the circumferential seam there is apt to be a slight difference in circumference between the fitting surface of the two sheets and this would mean that unless the sheets were drawn together very firmly, there would be a small gap between the sheets. As one rivet after another is driven, each rivet pulling a certain amount

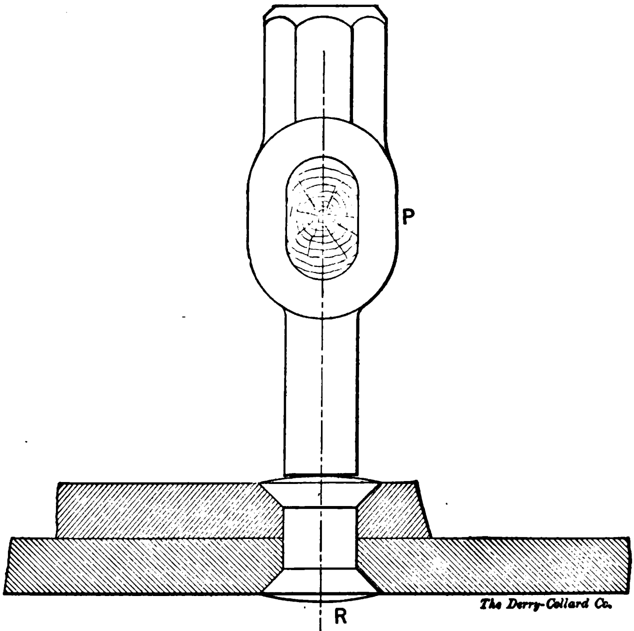


Figure 164

Knocking out a countersunk head rivet.

upon the sheet, there will be a time when the longest rivet will be relieved of its weight and we would have a rivet to be taken out.

Fig. 163 illustrates the method for removing a rivet which has an outside head. The punch P is set against the head of the rivet and is hit several hard blows with the sledge hammer. The head R will thus be removed by a failure of both shear and bending. The tit T of the punch is now entered upon the rivet and the rivet punched out of place. A rivet like the one in Fig. 164 is removed

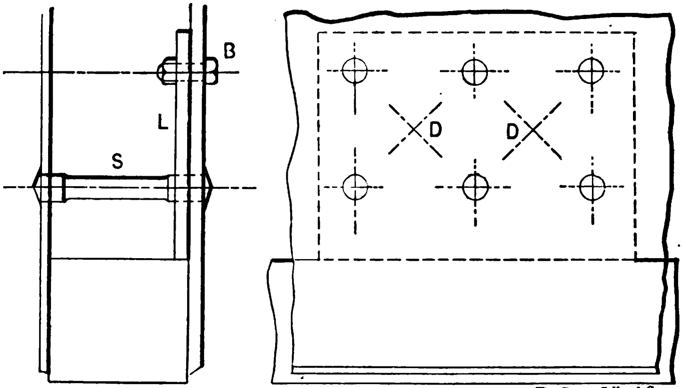


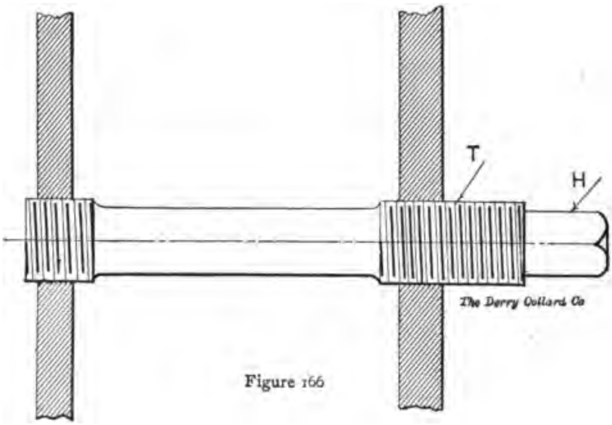
Figure 165

Fastening furnace bearers.

by applying the punch P as indicated. In this case the rivet is punched directly through the sheet.

There are other cases of bad rivets besides those mentioned. If the rivet is machine driven and if the boiler has not been raised to the proper height, a rivet will be driven with the head out of the center of the rivet. This can readily be seen on the boiler on account of the uniform pitch as the eccentricity of the head makes the pitch unequal.

Many boilers are supported upon the frame by means of "furnace bearers." These are frequently attached to the side sheet by studs and on account of the excessive weight of the boiler, filled with water, the studs are tapped into both the sides sheet and the liner. These studs are placed at the diagonal D, D, Fig. 165, joining the stay bolts. The liner L is held in place by several bolts B and the sheet is reamed and tapped for the stay bolt S. After several of these holes have been tapped and the stay bolts are screwed into place, one after the other of the bolts P are taken out, and these holes reamed out and tapped and stay bolts screwed into place. In this manner, all the bolts are removed and stay bolts screwed into their



Staybolt just put in place.

places. The liner L is thus bolted firmly in place. The studs for supporting the furnace bearer have a taper tap and are screwed into the boiler so as to make a steam tight fit.

Fig. 166 illustrates a stay bolt which has just been screwed into place and which has not yet been cut off. They are frequently nicked by hand at T and then the head H is knocked off with a hammer. The nicking is done by two persons, one holding a chisel and the other striking. After they have been cut off, either by hand or some style of machine, the stay bolt is riveted over by hand, after which the safety holes are drilled.

The crow feet, the T irons, etc., to which the stay rods are attached, are all riveted into place before the boiler is assembled. The bolts of the stay rods having been put into place, the rod is swung into position and the holes for the foot are scribed off from the sheet. These holes are drilled and the rivets are driven by hand. The crown stays are made after several different designs but are usually arranged with three rows on each side of the top center line and have either a solid head or else have nuts screwed into them on the fire box side of the bolt. They usually have copper washers between the nut and the sheet. These crown stays are screwed into place, nicked on the outside, broken off and riveted over.

Boiler Details.

It has been deemed advisable to gather the many fixtures, connections and detail parts together into one chapter. These details have been grouped under their special heads and will be treated separately.

Stay Bolts.

By far the most important detail of the boiler is the stay bolt. The kind of material, the design of the bolt and

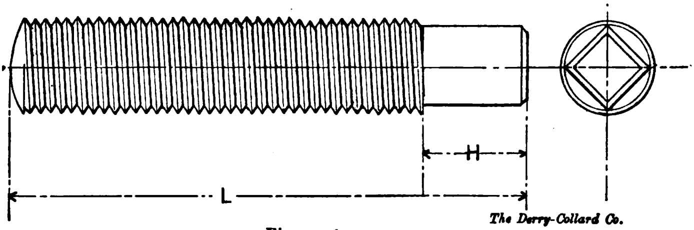
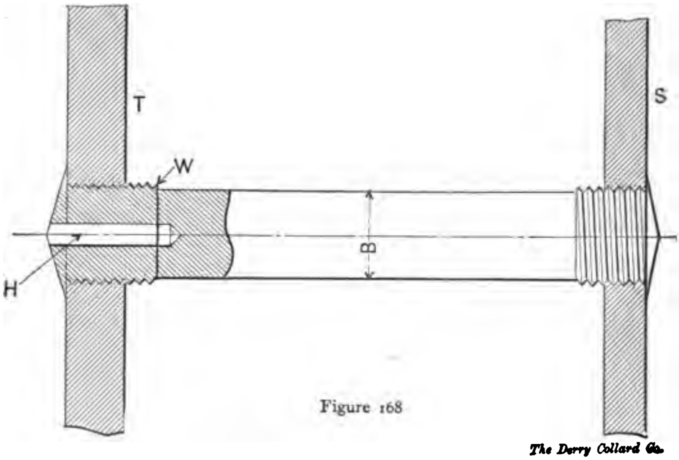


Figure 167

A common form of stay bolt.

the manner in which it is treated are all important items. In Fig. 167 we have a common form of stay bolt which is frequently used for staying the narrow portion of the water legs. The standard thread for these stay bolts among nearly all railroads is twelve to the inch. This gives a thread which is strong enough to resist shearing, and yet one which is not so coarse as to greatly reduce the area at the root of the thread. The square portion H is upset in the bolt machine for screwing it into place. In manufacturing establishments these bolts are made in large quantities varying in length by half inches for short ones, or by inches or two inches for long bolts.

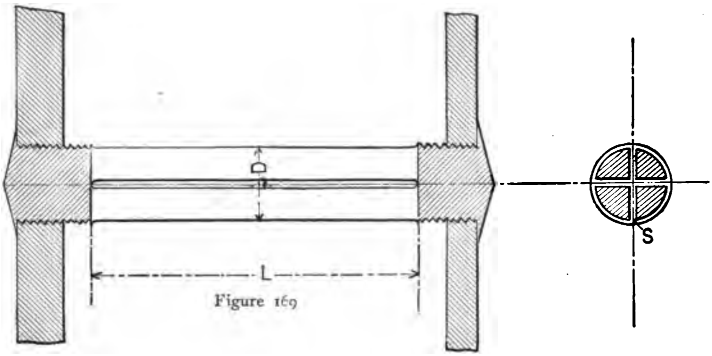
Fig. 168 shows a stay bolt which is very commonly seen on a locomotive boiler, T being the outside and S the



Stay bolt with drilled ends.

inside sheet. The bolt has been riveted over as indicated and the hole H drilled from the outside, deep enough to pass the point W, where the threads end. The bolt is either turned down or cut on a portion of the bolt upset from a bar of the diameter B.

These stay bolts usually break close to the outside sheet. This is due to the fact that the outside sheet is always cool and the inside sheet, especially when the fire becomes very hot, expands considerably. This carries one end of the stay bolt up higher than its normal posi-

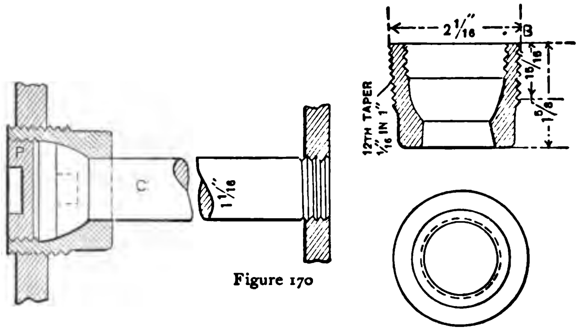


One plan of flexible stay bolt.

tion. The outside sheet being very thick, the end of the stay bolt is fixed and there is a severe bending action at W, which finally ends in a rupture. This occurs most frequently along the stay bolts on the top of the side sheet and for this reason boilers are now often built with a line of flexible stays at this point.

A number of flexible stays have been invented from time to time, some of them being satisfactory and others proving a failure. One method for making a stay bolt flexible can be seen by referring to Fig. 169. This represents an ordinary stay bolt with slots S milled clear through and at right angles to each other. The idea being to remove the metal in the center and instead of having one solid bolt of a diameter D, which would be very stiff, we have four individual sections, which is more flexible. Such a bolt has been used, its chief drawback being that it is rather expensive. Neither does it resist the torsional strain of screwing into place as well as a solid bolt.

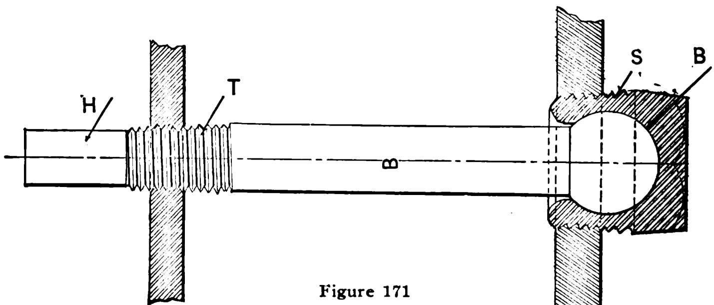
A flexible stay with a joint at one end is illustrated in Fig. 170, B is a brass fitting with a taper thread and is



The Derry Collard Co.

Flexible stay bolt.

screwed tightly into the boiler by means of a plug with a hexagon head. The plug is screwed into the inside and



The Derry Collard Co.

Still another form of flexible stay bolt.

has a shoulder that comes against the outside and drives the fitting into place. The plug is readily backed out after the fitting has been screwed into place. The portion marked C is made of a good quality of wrought iron and is screwed in by means of a square recess in the head. The bolt is then cut off on the fire box end and riveted over as usual. The joint would not be steam tight, therefore a plug P is screwed tightly into the fitting.

B, Fig. 171, is a stay bolt with a ball joint. This bolt is patented and is placed on the market in lengths to suit the various requirements and is put into place in the following manner. The threads at S and T are the same pitch. The head of the bolt H is turned and is entered

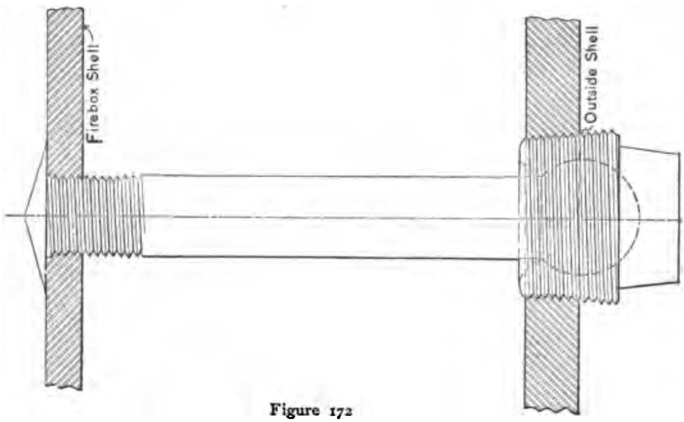


Figure 172

Flexible stay bolt in place.

from the outside into the fire box. H is then caught with a wrench and while one man turns the wrench another pushes the bolt in until the thread is caught at T. When the thread at S begins to enter the sheet, the fitting is turned by means of the hexagon on it and then by turning S the same as H, both are threaded in together. When S becomes tight, the bolt is in place. Then it remains to be nicked, broken off, and riveted over as usual. The part S is spun, by the makers, over the ball and numerous tests have shown that the body of the bolt has given way before S, has opened up.

A bolt, Fig. 172, is shown all riveted up into place. Fig. 173 illustrates a wrench that is used in putting the fitting, Fig. 170, into place. A is entered into the inside

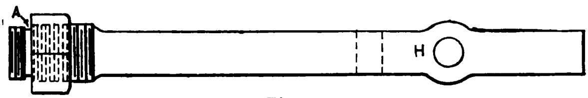


Figure 173

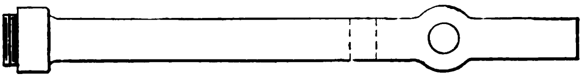


Figure 174

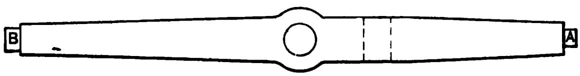


Figure 175 The Derry Collard Co.

Tools for flexible stay bolts.

tap and then the nut is brought down on the face of the fitting and the fitting screwed into place by the handle H.

Fig. 174 represents a solid wrench for the same purpose. Fig. 175 shows the wrench that is used for putting in the stay bolt and the plug. The small end A is used for the former and the end B for the latter.

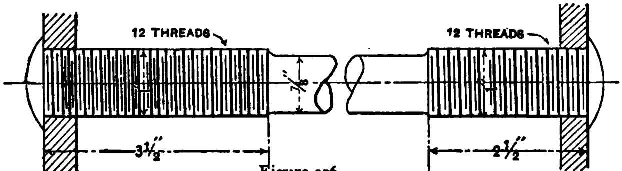


Figure 176

A common form of crown stay.

Crown Stays.

Many of the crown stays on the locomotive boiler are similar to the illustration Fig. 176. They are entered exactly the same as the stay bolt, and are cut off inside, and outside if necessary, and riveted over. These rods rarely break as they are long and, being near the center of the boiler, the expansion is more or less neutralized. Of course this is by no means the best crown stay and would perhaps rarely be used if it were not owing to the fact that few of the crown stays on a locomotive boiler, see Plate 2, are radial. When these crown stays are at right angles to the crown sheet, they are invariably made with solid head, as in Fig. 177.

This crown stay can only be used when it is placed

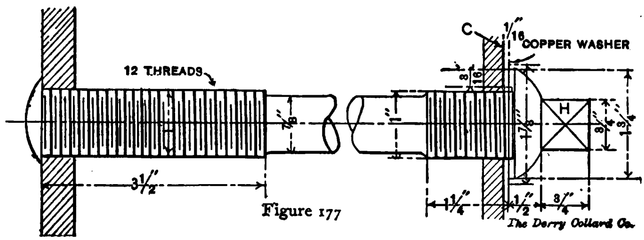


Figure 177

Another crown stay.

at right angles to the crown sheet, as the threads are straight. A copper washer C is placed between it and the sheet and when it is screwed tight into place it acts as a gasket to keep the joints steam tight. The square head H is used for screwing the bolt into place.

Sometimes a stay bolt is allowed to pass through for some distance and receive a nut, Fig. 178, instead of being riveted over in the fire box, like Fig. 176. A copper washer between the nut and the sheet serves to

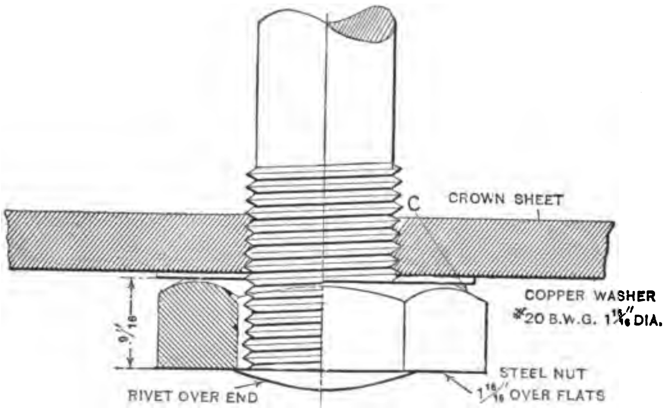


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Figure 178

Crown stay with nut and washer.

make the joint tight while the end of the stay bolt is riveted over against the nut, after the nut has been driven into place. Usually the two rows in front of crown stays are made flexible. One style is shown in Fig. 179, the idea being to allow the crown sheet to bend up as the tube sheet expands. As this tube sheet is usually straight, the expansion is a thrust against the crown stays and if these stays were solid, the crown sheet would be bent down immediately back of the tube sheet. This bending action would open up the seam and cause it to leak at this point. If we have a sling stay, however, Fig. 179, the crown is not prevented from rising and this defect is done away with.

Fig. 180 represents a detail of one of these sling stays. The lower portion is secured to the crown sheet by tapping E into the sheet and then screwing the nut in against a copper gasket C. A similar piece is screwed

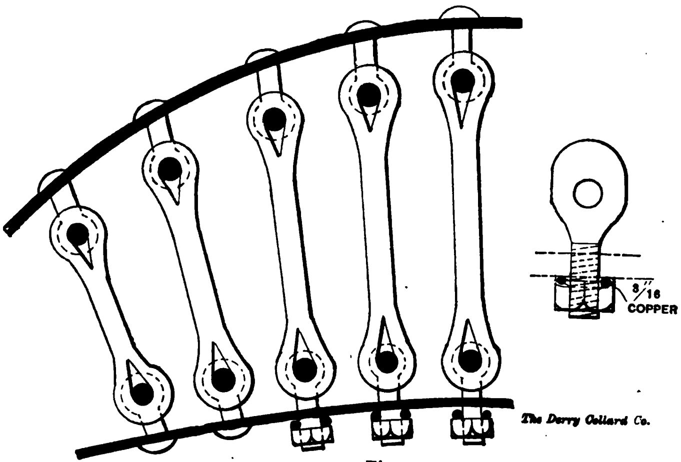


Figure 179
Sling stays in place.

in at F, and in this case is riveted over on the outside. B is a reamed bolt so as to make a snug fit. The straps L have elongated holes on the top to allow for expansion. This style of sling stay is frequently used over a great part of the crown. Where the stays are not radial to the

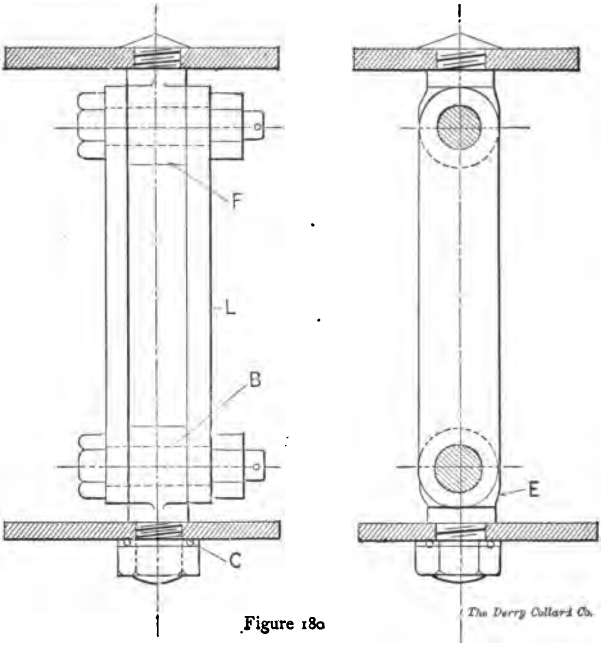


Figure 180

One form of sling stay.

crown sheet, they must be riveted over inside instead of having a nut as indicated.

Fig. 181 shows another style of sling stay. It consists of two T irons, one on top A and the other B, placed a distance above the crown sheet so as to admit of a free circulation of water. The bolts H are drawn up tight against the ferrules T. The bolts are made of steel and are turned to the exact size from hexagonal stock, on a screw machine. The holes to receive the bolts are reamed.

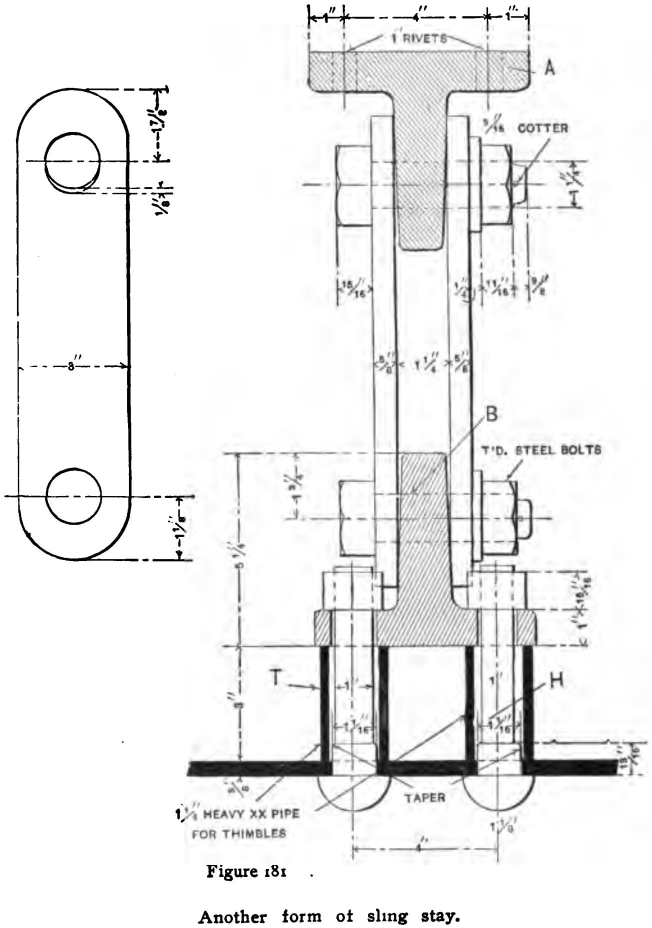


Figure 181 .

Another form of sling stay.

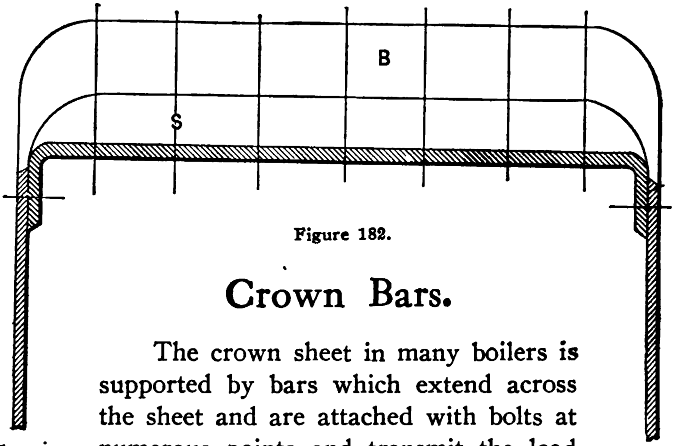


Figure 182.

Crown Bars.

The crown sheet in many boilers is supported by bars which extend across the sheet and are attached with bolts at numerous points and transmit the load either to the end of the bars and from thence to the side sheet or else to links and from these to the outside crown sheet.

Fig. 182 represents a crown bar which is supported by the side sheet. The bars B are placed in pairs and the bolts S are supported between them. The total load of the crown sheet is transmitted through this crown bar B to the ends E, which are turned down as indicated. The points E are allowed to bear only on the edge of the side sheets.

A cross section of a pair of these bars is shown in Fig. 183. The bars B are made of wrought iron about ¾ of an inch in width and five or six inches in height. They are cut off by a cold saw and then forged to suit the shape of a sheet iron templet the same as B in Fig. 182. The exact size of the material of these crown bars must be obtained from the length of the bars, the load upon it, and method of supporting the load. S is the crown bar bolt with a head H, which hooks over and keeps the pair of bars in place. F is a ferrule tapered off at the lower end so as to keep the crown sheet from burning, and also to admit of a better circulation of water. The bolt passes through the sheet and is screwed in place by a nut. W is a copper washer to make the joint tight. The bolt is riveted over on the outside of the nut.

Another arrangement of the bolt is indicated in Fig.

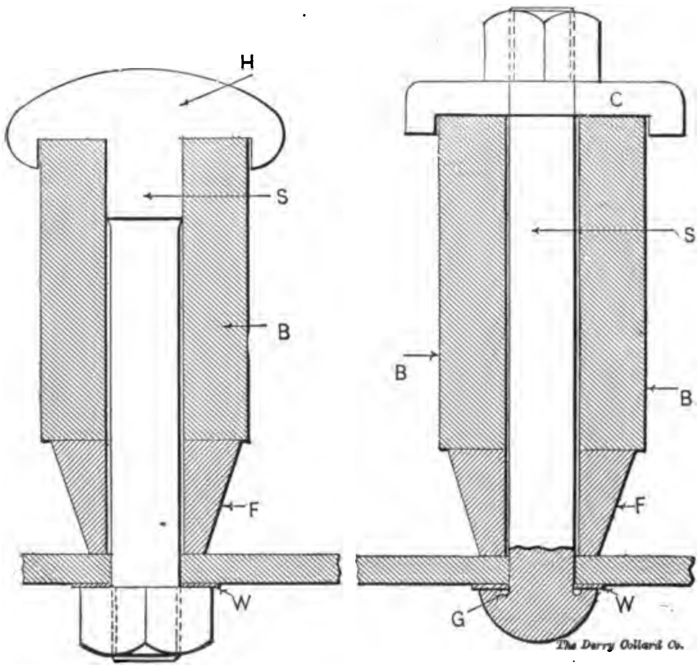


Figure 183 Figure 184

Crown bars and bolts.

184. In case the head of the bolt is on the fire box side, it is grooved out at G so as to make a better joint between the head and the copper washer W. C is a clip, which

serves to keep the pair of bars in place. In large manufacturing concerns these clips are made to standard size and are forged under the drop hammer. In Fig. 185 is seen another style of crown bar. T is a T iron bent to conform to the curvature of the crown sheet. The stay bolts are all placed at right angles to the sheet. The 2½

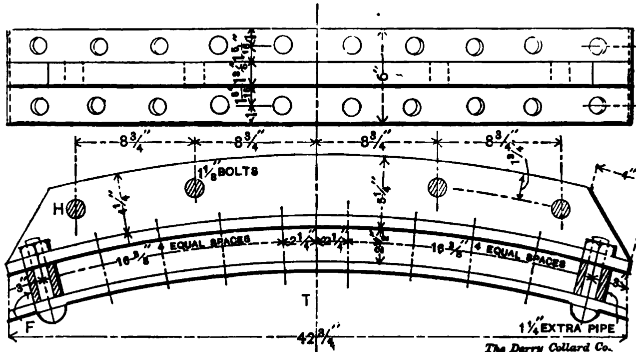


Figure 185

Another type of crown bar.

inch distance between the crown sheet and the T iron is obtained by the use of ferrules F, which are made of

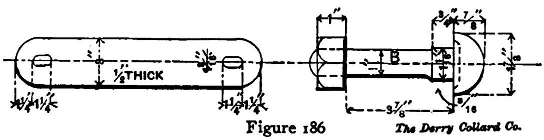


Figure 186

Crown bar link.

extra heavy pipe. The holes H are intended to receive links, through which the load is transmitted to the T iron on the outside crown sheet. In Fig. 186 is shown one of these links. They are made of one-half by three-inch wrought iron. The ends are sheared off round from stock which has been cut to the proper length. Sometimes the straps are heated and the ends cut round under the hammer. The bolts B are similar in construction to the one referred to in Fig. 184.

In Fig. 187 C is the T iron which is shaped to fit the outside crown sheet. It is cut off to the length L, either

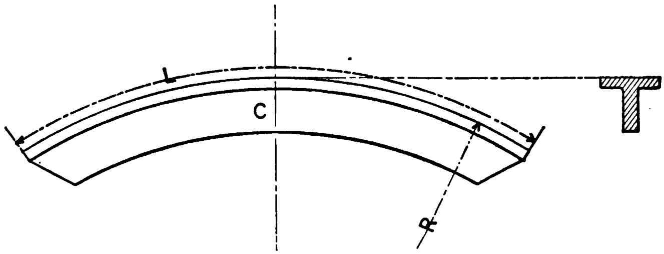


Figure 187

A T iron crown bar.

by a cold saw or else nicked and broken off. R is the inner radius of the outside crown sheet. This T iron is riveted to the outside crown sheet with a sufficient number of rivets to withstand the pull from the links. The holes are drilled to suit the links and reamed to fit the bolts. The T irons for the crown bar stays are especially rolled for that purpose and are made extra heavy in order to withstand the stress brought upon them. In Fig. 188 is a very heavy section and one which is largely used for heavy boiler work. Fig. 189 represents a much lighter section and is used for cases where the load is not so severe. Two other sections, Fig. 190 and 191, are illustrated for still lighter work. These sections are sold in the open market and are very generally used by railroads and boiler manufacturers.

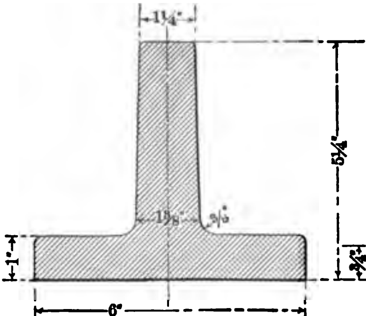


Figure 188

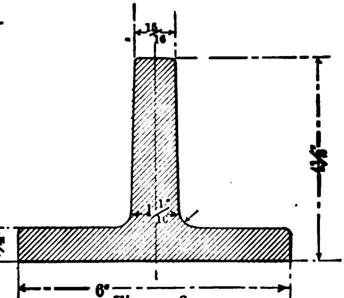


Figure 189 The Derry Collard Co.

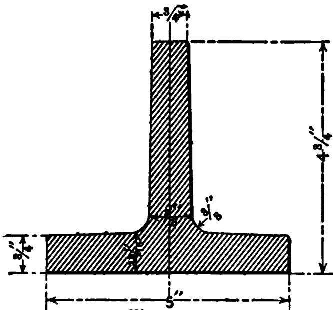


Figure 190

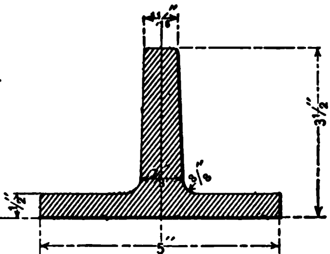


Figure 191

The Derry Collard Co.

Sections of T iron used for crown bars.

Throat Stays.

There are many varieties of stays used for the throat sheet. Fig. 192 is a style where R is a regular stay rod and F is a regular foot. B is a stay bolt which is either tapped into the sheet with a square end in the fire box side or else it is entered into the sheet with a copper washer between the head and the sheet. This bolt is

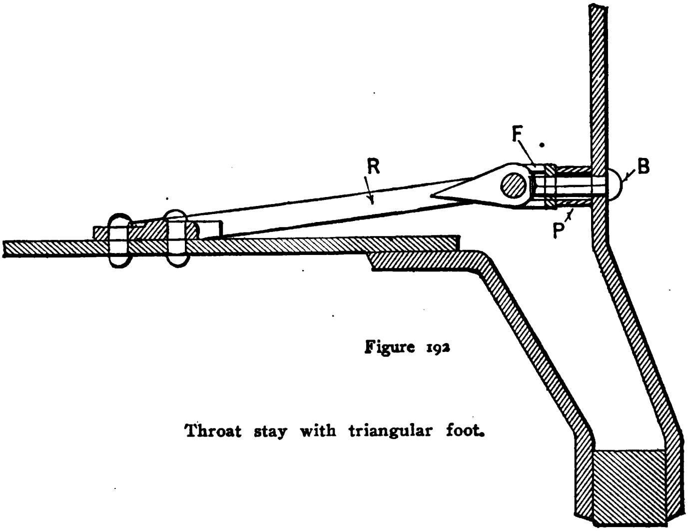


Figure 192

Throat stay with triangular foot.

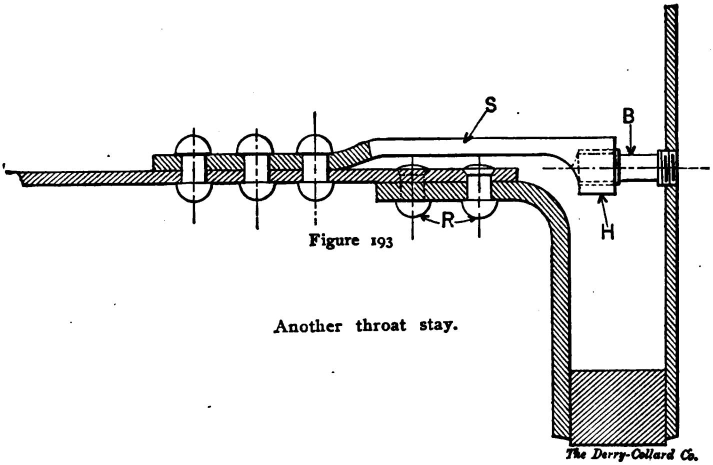


Figure 193

Another throat stay.

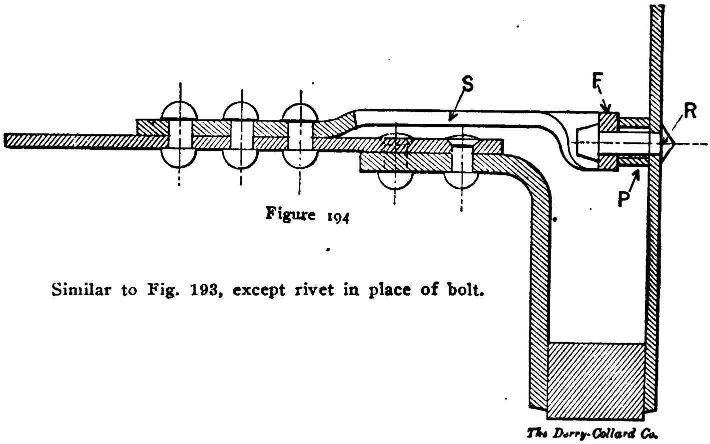


Figure 194

Similar to Fig. 193, except rivet in place of bolt.

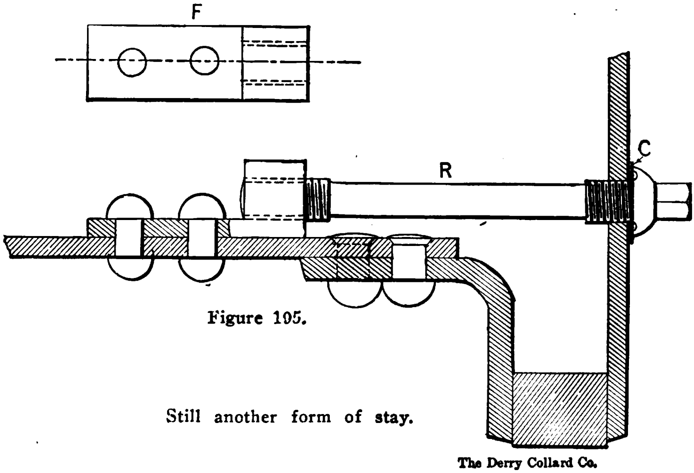


Figure 105.

Still another form of stay.

drawn tight against a piece of extra strong hydraulic pipe P, allowing a free circulation of water around the stay rod support. When the connections for the throat stay are somewhat lower than in the illustration, the style of stay, Fig. 193, can be used. S represents the stay rod which is a flat bar of iron and has a head H at one end. They are made under the steam hammer out of round stock of the diameter at H and drawn down to the required length. When these rods are long they are welded to straps in order to save time in drawing them out. The stay bolt B is a regular stay and tapped through the back tube sheet and into the head H. The bolt is then riveted over on the inside in the same manner as the other stay bolts. The rivets R are countersunk on the inside to clear the throat stay. Sometimes this style of stay rod would be too near together along the line of the throat stays and the circulation be interfered with. For this reason a throat stay like that seen in Fig. 194 is used. This is a common form of stay rod with a solid foot welded on one end. The rod S is twisted so as to bring the foot F lower at right angles to the other part of the rod. The foot takes two rivets R, one on each side. The rivet is entered into place and headed upon the inside by hand, the pipe P serving as a distance piece.

When the line of the throat stays is made somewhat higher than this illustration, the style shown in Fig. 195 may be used. The foot F is a drop forging or is drawn out from the bar. The stay rod R is tapped into the sheet and into this foot. C is a copper washer. It is also seen that the rivet heads in the throat seam are countersunk as they always should be, whenever the clearance is small, as mud collects quickly around these heads and soon interferes with the circulation.

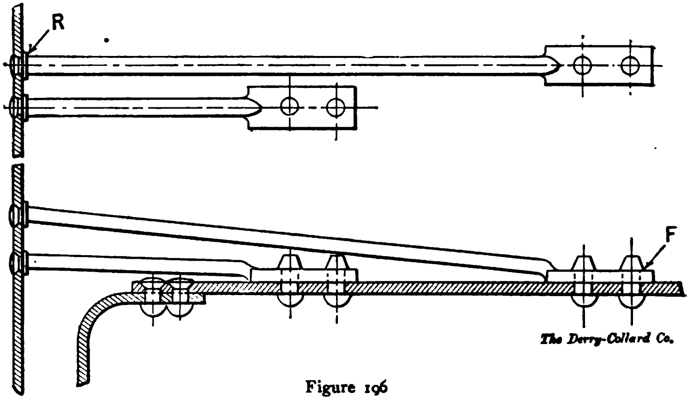


Figure 196

Long and short throat stays.

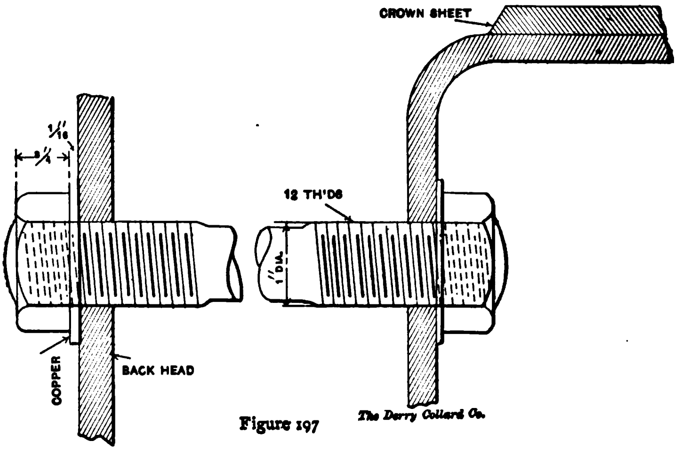


Figure 197

Stay for back heads.

Stay rods.

In Fig. 196 we have a series of long and short throat stays. They are staggered and riveted into the front tube sheet. A ring R is forged on the end of the rod or else the rod is upset to this amount. It is entered into the drilled hole on the tube sheet and is riveted over against the countersink as indicated. The holes for the foot F are scribed from the boiler and then drilled to suit these marks. Fig. 197 shows a style of stay bolt that is used for staying the back head to the back fire box sheet. It is screwed in as a regular stay bolt and then the nuts screwed up against copper washers, both in the fire box and the outside.

Stay Rods.

The Wootten boiler, Plate 1, shows several stay rods similar in construction to Fig. 198. R is the stay rod proper and F is the foot. These rods are welded together at W, in lengths from ten to twelve inches. They are then pieced out to suit the required distance for the various boilers. The foot is jigged for the drilling of the two holes H. This foot is riveted to the side and end of the boiler, and the rod H is secured to the sheet by two or three rivets. When it is desired to have the rod at right angles to the holes here shown, a style represented by Fig. 199 is used. The holes H are closer together so as to reduce the bending on the foot when the rod R is in tension. These are made in the same way as Fig. 198 and in manufacturing concerns are made to a standard size.

The most common form of stay rod, and one which is figured up complete for this size, is illustrated in Fig. 200. The end A is a drop forging and has a part of the rod R attached to it. The exact length of the rod is obtained from the boiler, and R is then welded up to suit this length. The end A is reduced in thickness at the second rivet. This is done to give uniform strength through the rivets. The end B is forked so as to receive a crow foot T iron or some other means of connection. This forked end is welded to the rod R and the hole H is drilled from the solid.

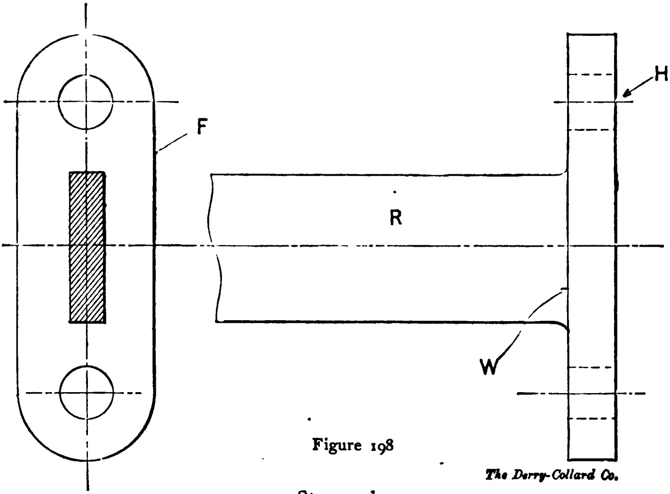


Figure 198

Stay rod.

In Fig. 201 we have a style of stay rod which is used to some extent. The end A is forged similar to the rod just referred to, while the end B is welded to the rod R as indicated. B is either welded to the rod as shown or at right angles to it, although there are cases where the end B is set at an angle to either one of these positions. In this case the rod is heated at one place, taken to the boiler, held up in position and twisted so as to fit snugly in place.

On some boilers we find the front and back tube sheets stayed to each other by long stay rods similar to Fig. 202. They are tapped into the front and the back tube sheet and have nuts clamped up against washers as indicated. The rod is then riveted over the head of the nut. The bar is upset on the end for the thread so that the diameter D is about the same as the root of the thread.

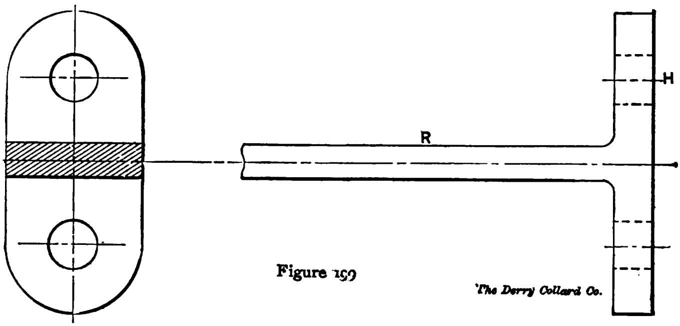


Figure 199

Another stay rod.

Stay Rod Feet.

Many of the stayed plates are supported by the style of stay rod indicated in Fig. 200. The end B may take any number of feet, depending upon the size of the area of the surface to be stayed. These feet have two or more bolts. A two bolt foot is represented in Fig. 203. The holes H are drilled with jigs and the hole K is drilled from the solid. The width B is made to suit the stay rod and as far as possible is kept to a standard figure. Fig.

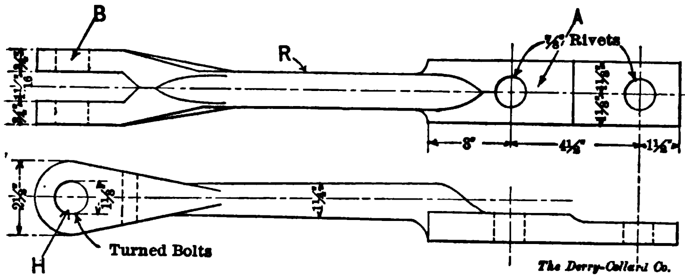


Figure 200

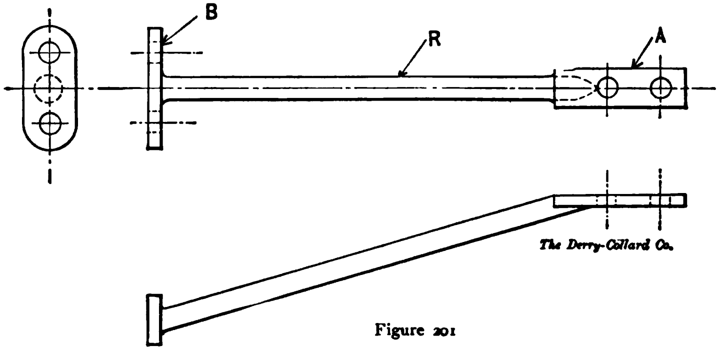


Figure 201

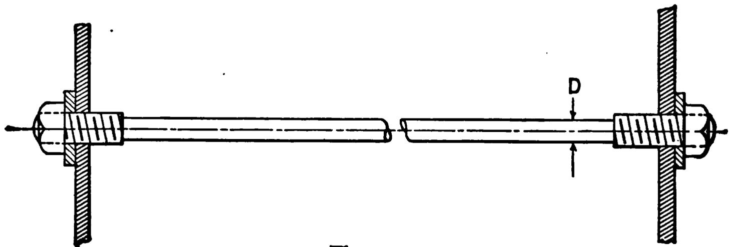


Figure 202

Different styles of stay rods.

204 illustrates this same style of foot which is convenient for a stay rod at right angles to the style, Fig. 202.

Fig. 205 represents a crow foot which takes three holes H for rivets. They can be thrown around at any

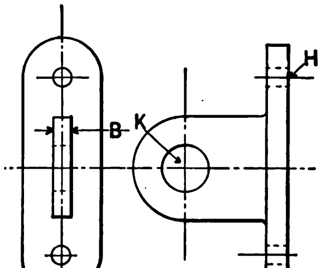
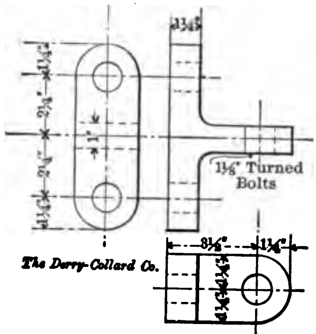


Figure 203
The Derry-Collard Co.

Two bolt foot.



The Derry-Collard Co.
Figure 204

Two bolt foot.

angle but are usually placed in such a position that the rod can be swung out radially against the side of the boiler. For convenience in staying, these crow feet are

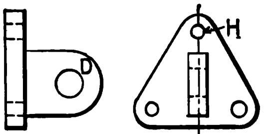
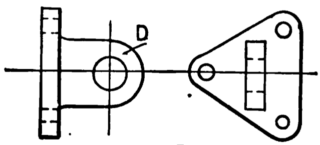


Figure 205
The Derry Collard Co.

Crow foot.



The Derry Collard Co.
Figure 206

Crow foot.

made with the part D for the stay rod, turned around at right angles, see Fig. 206. The other end of the stay rod A, Fig. 200, is frequently terminated in a foot like

Stay rod feet.

Fig. 207. In this case the two ends of the stay rod are jaws of the same size and shape. This foot takes two or three rivets, depending upon the size of the stay rod, and the section of this foot is frequently made larger at the end nearest the rod. This foot makes a good substantial job. In Fig. 208 is a style of foot which was very largely used a few years ago and is still used to some extent, owing to its cheapness. It is made of bar iron, given a

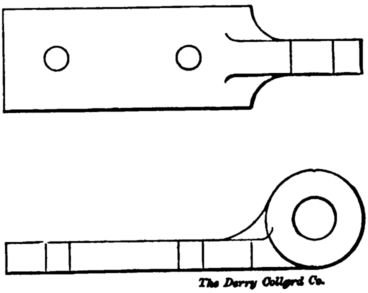


Figure 207

Another foot.

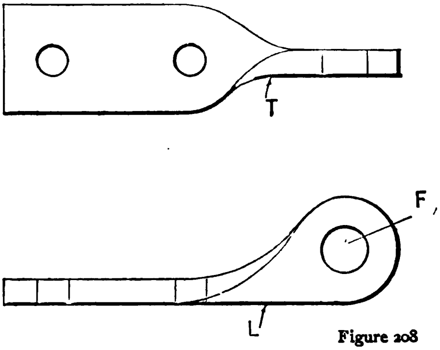


Figure 208

A cheap form of foot.

twist at T and set up so as to be straight along the lower line L. The trouble with this foot is that if a force F pulls upon it, it will bend at the first rivet, and then we have a loose stay rod at the outset.

Fire Box Details.

On all locomotive fire boxes which extend down between the frame, some form of furnace bearer must be employed to support the rear end of the boiler. The boiler is bolted rigidly to the cylinder at the front and as it expands when heated some provision must be made on this furnace bearer for taking care of this movement. Fig. 209 represents the general arrangement of such a furnace bearer. F is the locomotive frame, B is the furnace bearer, C is the furnace bearer clamp, G is a filling in piece between the fire box and the frame and must

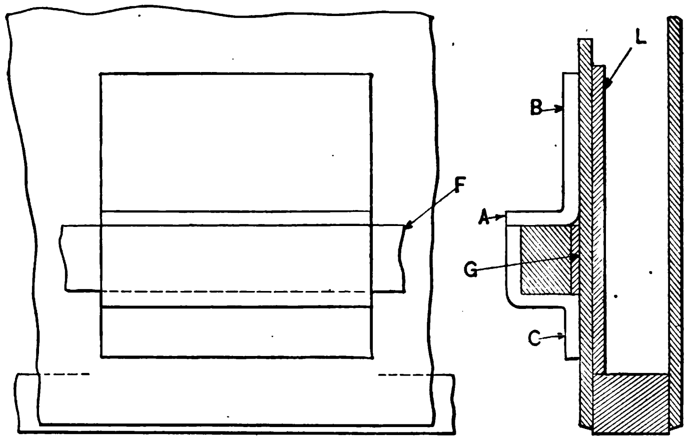


Figure 209

General arrangement of furnace bearer.

always be made to suit the variation in the width of the fire box for each locomotive. L is the liner which is intended to strengthen the sheet at this point. With this construction the boiler can readily slide back and forth on the frame.

The furnace bearer is made of wrought iron plate and is always somewhat longer on the end A for matching. The stay bolt heads are chalked or given a dab of white lead and the clamp is placed against these heads in its proper position. The marks on the back of the plate show the location of the stay bolt heads. W is then put under a drill press and each one of these places is counter sunk. It is now tried to the boiler and any places that do not fit up are noted, countersunk and fixed to suit. Then the holes in the studs are drilled, and the end is planed off to suit the clamp. The clamp is fitted in the same way. The office of the clamp is to keep the boiler from jumping up and down between the frames. Any other style of furnace bearer, whether of wrought iron, cast iron or steel, is fitted in much the same way.

The mud ring is rightly named for it is here that the mud settles. On this account we find the arrangement shown in Fig. 210 used by a number of railroads. The pipes P have a series of holes drilled along the lower line and are coupled up as shown to blow off cocks C and D. When the water cocks are open, the pressure of the steam squeezes the water, mud, dirt, etc., through these holes and on through the pipe to the blow off cock. The studs are located bear the bottom of the water space and it is upon these that the clearing pipes rest. The studs have a tapered top near the head and are screwed through the outside sheet only. The pipes are entered through the holes H and are screwed together by means of alligator wrenches placed in the holes K. Ordinary corner plugs are then placed in the holes H and are only taken out in case the piping is required to be removed.

Fig. 211 shows a very common arrangement of the locomotive grate. This style of grate is known as the finger bar and on account of its simplicity it lends itself to a much wider use than many other styles of grates. A and C are the end bars and are provided with an extra

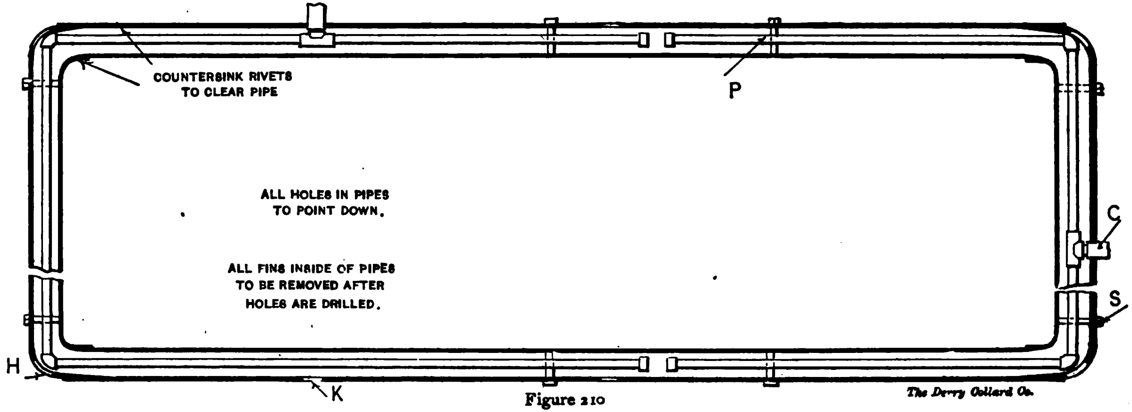


Figure 210

Arrangement for cleaning mud ring

number of fingers as indicated. All the remainder of the bars have staggered fingers and are exactly alike. In this grate, the bar C comes over the axle and as the ash pan must encircle the axle, the arm for rocking this bar will not clear the pan. For this reason this bar has a square trunnion and has no rocking motion whatever. D is the drop plate, which is operated through a link and a rock shaft, and finally a handle T. The handle H can be raised out of the slot and by throwing it back and forth the bars are rocked. When the handle is dropped the bars are held in the central position. The side frames for grate are supported on studs S. All bars and the drop plate are made of cast iron. All the shifter rods, links, shafts, handles, etc., are forged from wrought iron.

There are as many different styles of grate bars and methods of supporting them as there are different kinds of locomotives. The grate which has just been described is one of the most satisfactory for general use. The air space is larger in this style than in almost any other. In Wootten boilers the grate bars frequently extend the whole length of the fire box and have water tubes between the grate bars. These bars extend on through the rear end of the boiler and are rocked by handles at the rear end. Some railroads have a drop plate at each end of the grate and others have a drop plate in the center. Still other grates have neither and depend entirely upon the rocking of the bars to break up the clinkers and to clear the fire.

Fig. 212 represents a wood burning grate. In order to make such a grate satisfactory, several things must be borne in mind. In the first place, a wood fire, unlike one of coal, has free passage for air and on this account does

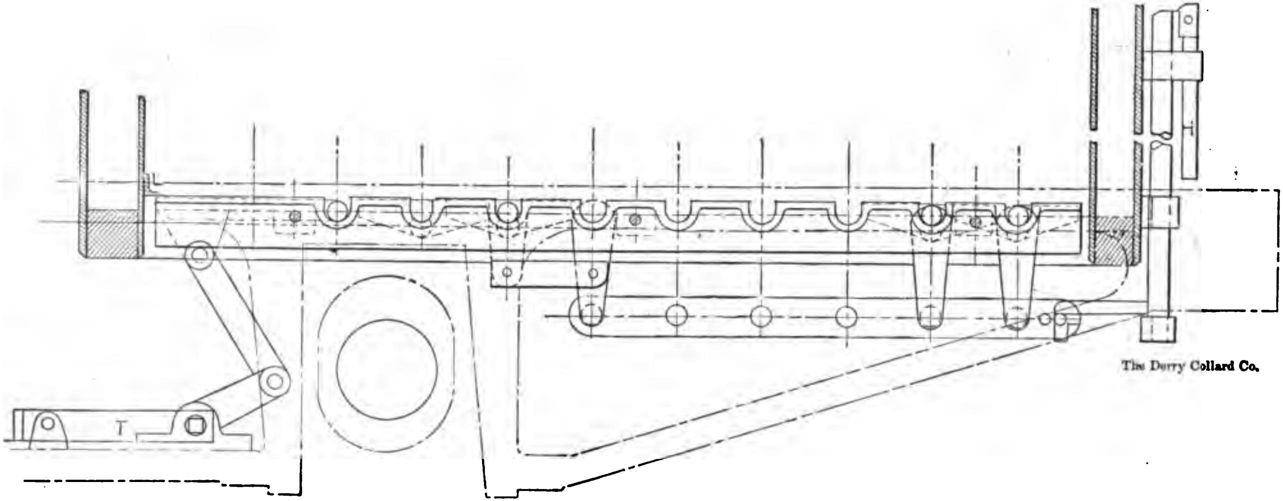


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Figure 211

A common arrangement of locomotive grate.

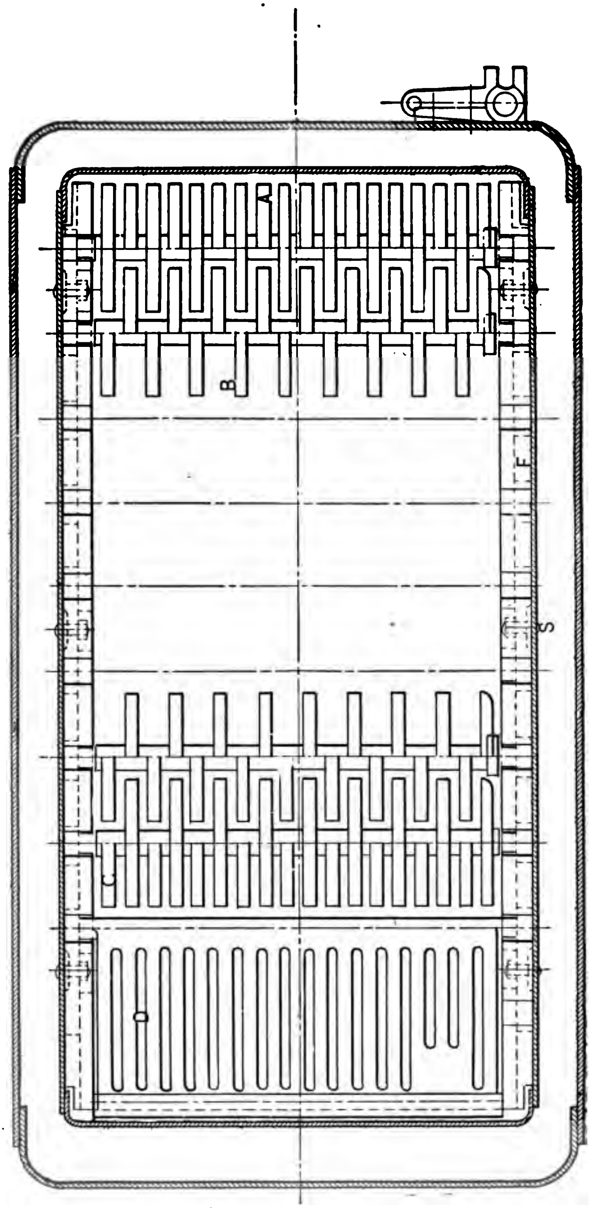


Figure 211 A

Top or plain view of Figure 211.

not need to have nearly as large a percentage of air space. This figure shows a half plan view of a grate and it will be noted that the air passage covers only a small portion of the entire grate. The bars B are blank for a distance

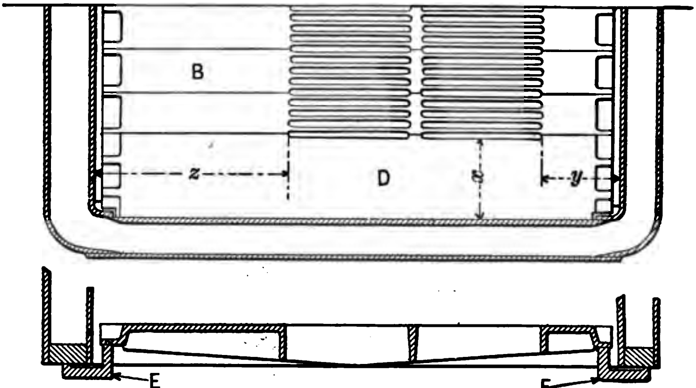


Figure 212

Grate for wood burning.

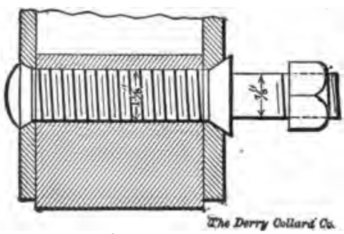


Figure 213

Mud ring bolt.

Z on the front, and Y in the rear end, and then we have a bar D for a distance X without any holes in it. These dead bars fit snugly against the fire box sheet and are usually seated with clay. The idea is to make all the air come in through the thickest part of the fire, instead of having an enormous rush of cold air up along the side of the sheets and through the tubes, which would cool the boiler instead of heating it. These bars are supported by cast iron knees E, which are bolted up against the bottom of the mud ring.

There is scarcely a boiler with two or three studs to support the grate side frame, which does not leak around them. For this reason, various methods of supporting

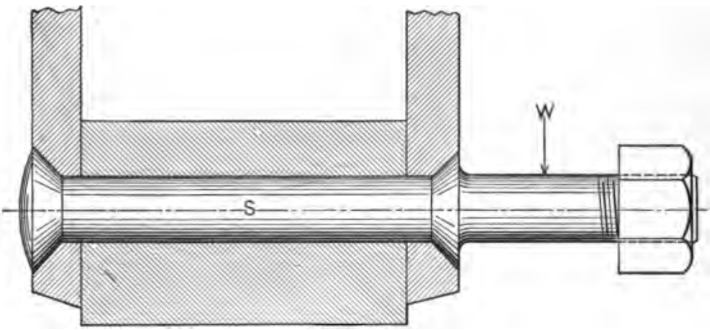


Figure 214

A cheap mud ring bolt.

the grate have been used, most of which are arranged so that the bolt will pass through the water space frame.

Fig. 213 shows one of these bolts. They are turned out on the screw machine from stock of a diameter of the countersunk head and are threaded so as to be screwed clear through the frame. After being screwed tightly into place they are cut off on the outside and riveted over.

A much cheaper style of bolt is represented by Fig. 214. This is entered into place and is headed up on the outside, while the bolt is hot. It is open to the objection, however, of gradually working loose after a load W shakes and bumps around on it.

Fig. 215 illustrates a better construction, but like most good things is more expensive. This bolt is all made in the screw machine, except the portion C which has a taper thread. These bolts are central and the threads cut in an engine lathe. It is tapped so as to

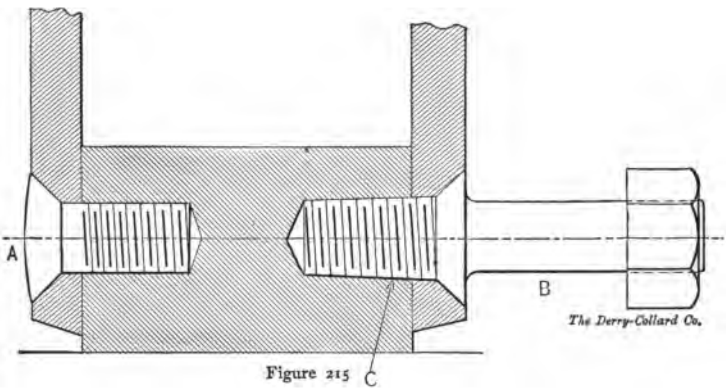


Figure 215

A better but more expensive plan.

screw in snugly. A is a patch bolt which is screwed into the frame and riveted over in the same way as the bolts around the corner of the water space frame.

The fire doors of most locomotive boilers are made of cast iron with deflecting plates on the inside, supported by studs to prevent undue heating of the fire door. These studs must be countersunk to clear the heads of the stay bolts and are chipped to fit snugly against the head of the boiler. The door is held to the boiler by studs which are tapped into the back head and fit a taper tap. They are provided with some style of damper for admitting a flow of air and are frequently arranged with a handle that can drop into several notches to allow the door to stand open to some extent and thus check the draft. The latch is placed on the right hand side of the door.

Steam Connections.

The dome of a locomotive boiler is intended primarily as a place from which dry steam can be obtained. In a boiler where water is evaporated so rapidly, some water is always carried along with the steam. The dome is some distance above the water and gives the steam some chance to be separated from it.

Fig. 216 shows a dome complete. F is the flange, B the body, and R the ring, all of which are made of steel plates. C is the dome cap and is made either of cast iron or steel, depending upon the size and conditions. S is the safety valve. These valves are entered into the cap and the fitting is riveted over on the inside. Three bosses are provided for safety valves. Two of the valves are frequently pop valves and the third one is provided with a lever. They are usually set to blow off at slightly different pressures and a little above working boiler pressure. The cap C is turned off on the bottom and is entered into the dome ring by a flange T. A groove is cut around at J into which a copper wire gasket is laid.

Fig. 217 is a dome taken from a Wootten boiler, and on account of the limit in height, the dome is very low; this is a 30-inch dome and is figured up completely showing the cut out which is necessary for the throttle. This cut out should be made as small as possible in order to give more strength to the sheet. It is frequently very much out of the center of the dome.

The old style of throttle, which admitted steam both

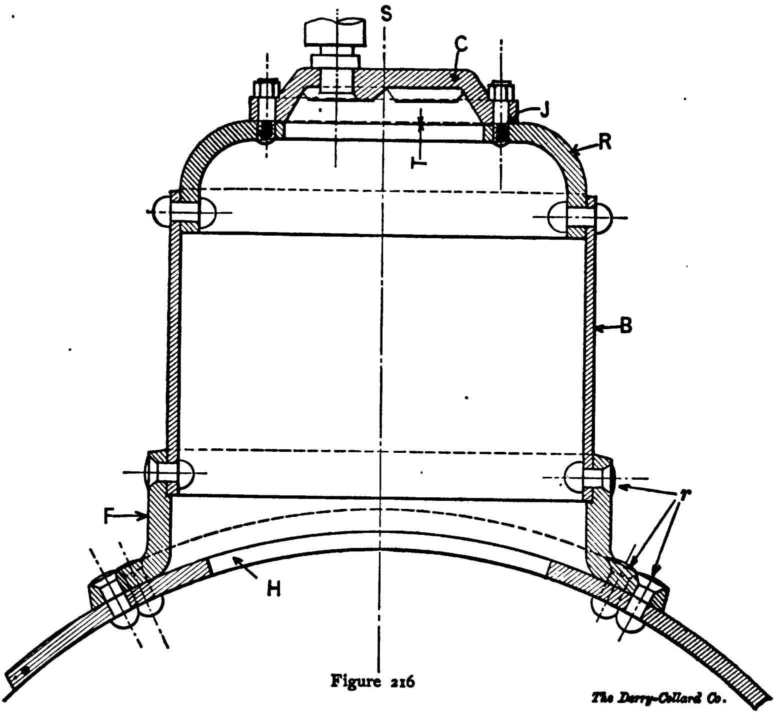


Figure 216

A complete dome.

on the top and the bottom, is being replaced by some form of throttle which admits steam from the highest and of course the dryest portion of the dome. A good example of one of these throttles is seen in Fig. 217A. This is known as the "Rushton" type of throttle. The steam enters the throttle at S_1 and S_2, the latter coming through the center of the valve at V. The valve is raised with a bell crank by the rod R, which extends on through to the throttle lever. The pressure, which tends to keep this valve closed, is exerted on the difference of the areas in the upper and the lower opening and this is greatest when the valve is closed. For this reason a pin P_1 near the

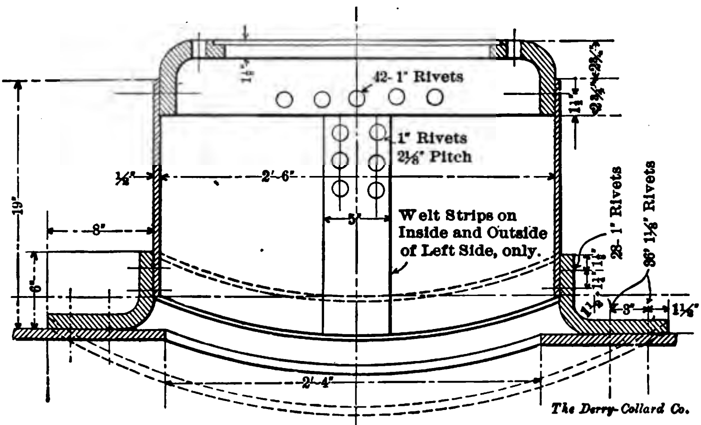


Figure 217

A low dome from a Wooten boiler.

fulcrum, first comes into operation and on account of the short arm, the valve is readily raised. After it has advanced a certain distance, the pin P_2 comes into play and the valve is opened more rapidly. H is the lug for bolting on the dry pipe. L takes a cross brace which is supported to the side of the dome. The pipe Y is altered to suit the various heights.

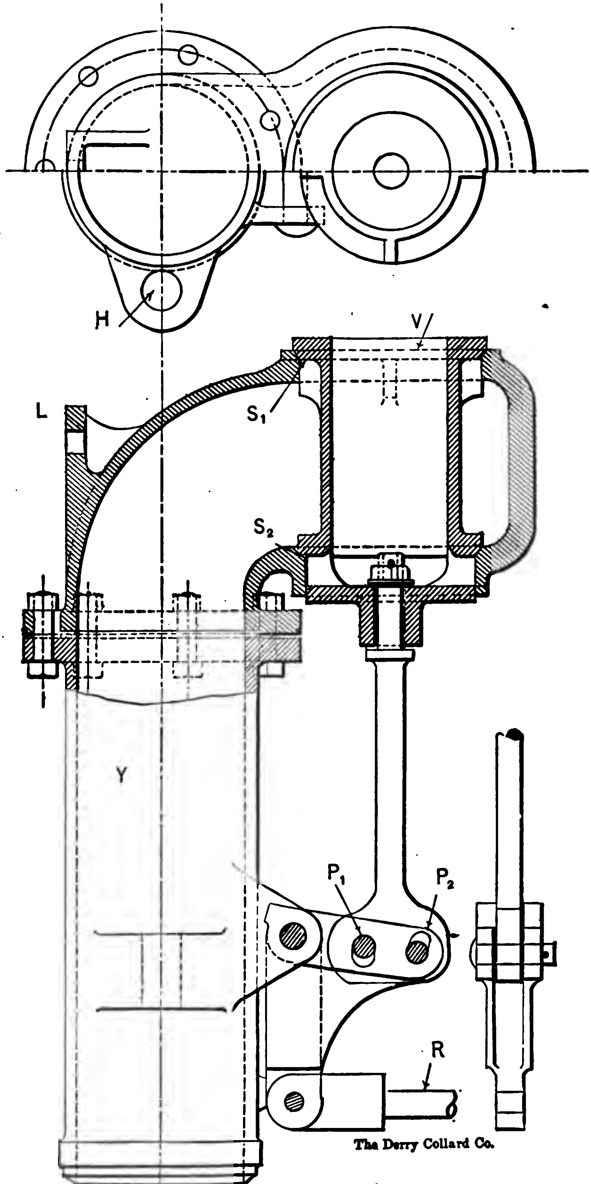


Figure 217 A
The "Rushton" type of throttle.

Brace for throttle.

Fig. 218 shows the method for supporting the throttle pipe. The brace B is bolted to the pipe at H and riveted to the dome at K. It is necessary that this bracket be well fitted up as the total weight of the throttle and

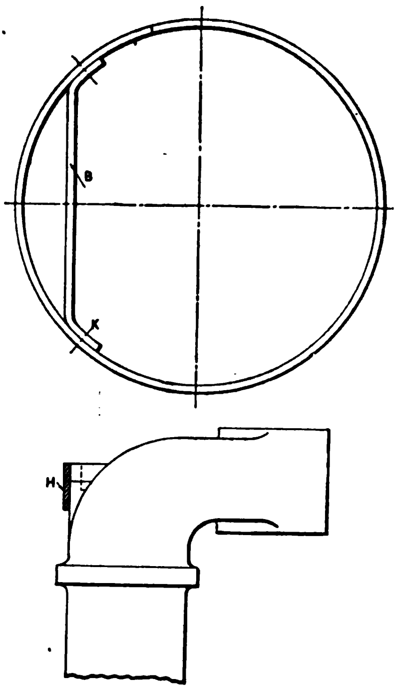


Figure 218

Supporting throttle.

dry pipe is apt to come upon it. The dry pipe is supported in several places by bands as indicated by Fig. 219. They are made of wrought iron about 3/8 by 2 inches and are riveted to the boiler at R.

The height of the dome above the water is usually sufficient to prevent the slop and splash from the boiler, but in large boilers, especially the Wootten and Belpaire types, dash plates must be provided to break or check the flow of water in stopping and starting the engine. One

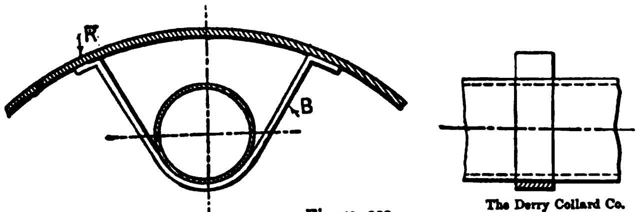


Figure 219

Dry pipe support.

of these plates is shown in Fig. 220. They are made of regular boiler plate ⅜ or ½ inch thick, depending upon

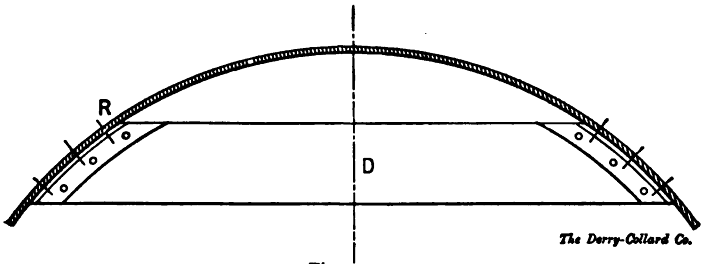


Figure 220

A dash plate to keep water out of dome.

the width and length, and are supported by angle irons riveted to the side of the boiler by rivets R.

The connection between the throttle pipe and the dry pipe is made by means of a ball joint of a radius R, Fig. 221. The curve is turned on the throttle pipe with a forming tool and is cut out of the dry pipe by a ball or rose reamer. A strap bolt B holds the dry pipe to the throttle by means of keys K. The hole H is rough cored, C is made of cast iron and W of wrought iron or copper. On account of the expense of copper pipe, the cast iron piece C is frequently made very long and then is joined to the front end by a small piece of copper pipe. The connection made between the two is made by means of a copper pipe D and wrought iron rings E. The rings are

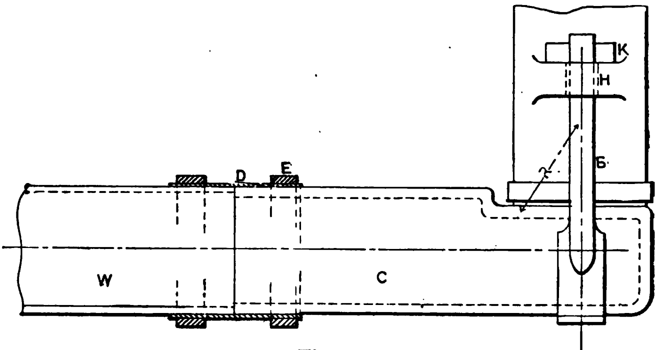
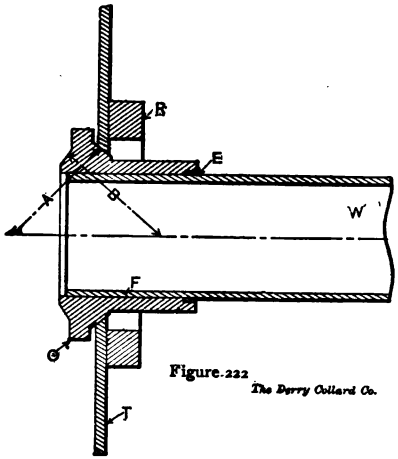


Figure 221

Connection between dry and throttle pipes.

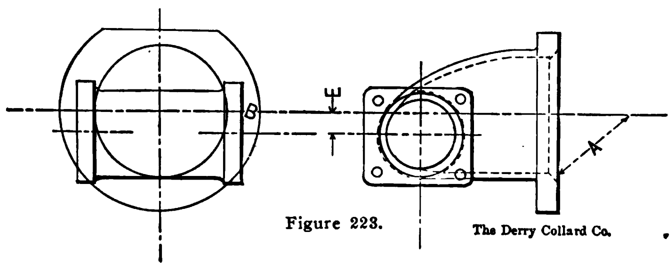
shrunk on and the copper is calked underneath it, so as to make the joint steam tight. Of course, there are other ways of making this joint but this is shown as it represents the usual form.

Fig 222 shows the connection at the front end of the dry pipe, T is the front tube sheet and R is the front tube sheet ring, C is the cast iron ball connection which has a ball joint with a radius A in the tube sheet and another joint with the radius B for the steam pipe elbow. The piece C is finished all over and is bored out at E, to take a copper ring and also bored out at F to make a snug fit with the dry pipe W. After the pipe has been entered through C to the proper distance, the ring E is calked so as to make a steam tight joint.



Front end of dry pipe.

The dry pipe must all be put together outside of the boiler. Forthis reason the end of C, Fig. 221, is dropped down as indicated in order to bring the circular section of the throttle pipe close to the center line of the dry pipe. This is necessary in order that the whole thing will enter the hole in the front tube sheet. The elbow for the steam pipe is represented in Fig. 223.



Elbow for steam pipe.

The ball joint for the dry pipe is indicated by A, while the ball joint at B receives the cast iron steam pipe that leads to the cylinder. On account of the peculiar construction of the steam pipe, this pattern is very expensive and in order to avoid the necessity of making new patterns, this elbow is altered and the distance E between the dry pipe center and the steam pipe center is changed. Sometimes the steam pipe center is above and other times below. The

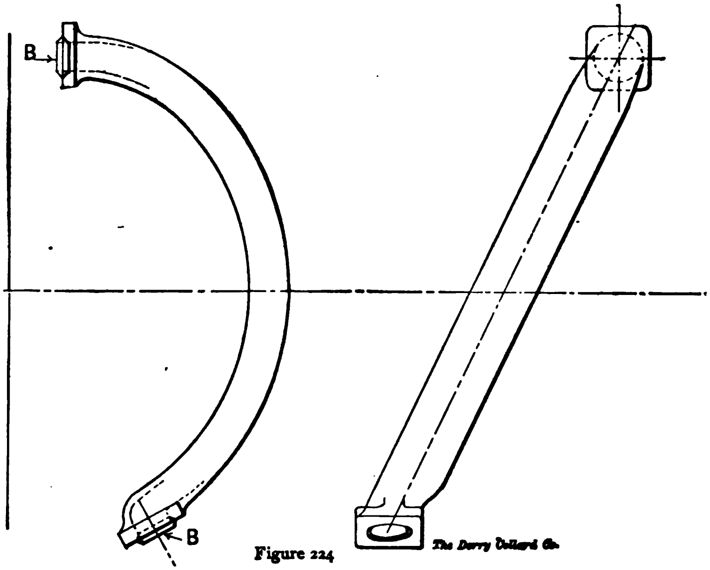


Figure 224
The steam pipe.

limit above would be determined by clearance between the flange and the boiler sheet and the limit below is determined by interference with the draft deflecting plate, etc.

A steam pipe is represented in Fig. 224. B and B are ball joint connections. It is impossible to swing a dry pipe and turn this ball connection on the pipe and for this reason the pipe is bored out and reamed. Then the ball joint ring makes the connection between the pipe and the elbow on top and the pipe and the cylinder on the bottom. The connection to the cylinder is usually made on an angle as shown in this figure. Sometimes we find the connection made at right angles, Fig. 225, and again there are cases where in this connection the pipe is carried down and the cylinder cored out so that it comes below the boiler, as indicated in Fig. 226. The advantage of this connection consists in being more readily chipped and fitted to the boiler in the erecting shop.

In Fig. 227, E illustrates a common form of exhaust pipe. The height L is usually determined by experience

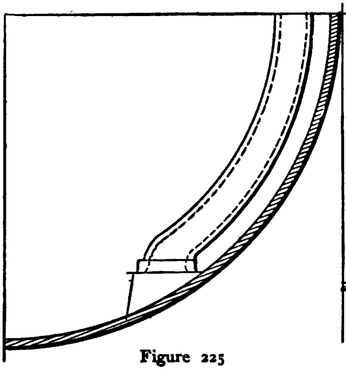


Figure 225

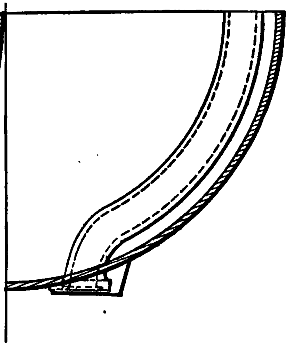


Figure 226

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Steam pipe connections.

as is also the nozzle N. It is the exhaust steam that creates draft in the boiler and the size of this nozzle determines the speed that the steam rushes out. For this reason several sized nozzles are sometimes furnished so as to meet the varied conditions of full load, speed, etc. The pipe is planed off on the bottom and is bolted on to the cylinder. Sometimes a central rib divides the two sides of the exhaust and extends up very near the top but more frequently both sides of the exhaust enter directly into a plain exhaust pipe.

As it is necessary to have dry steam for the main cyl-

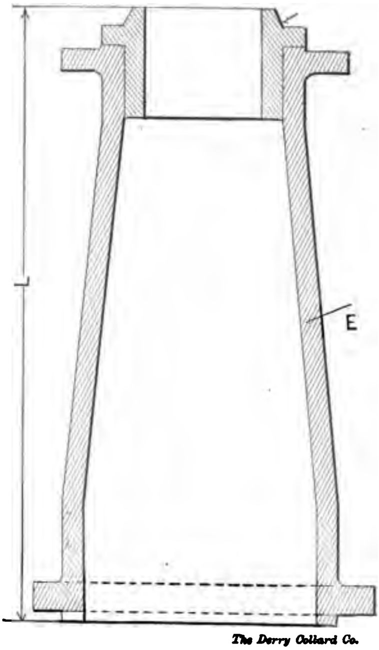

Figure 227

Common form of exhaust nozzle.

inder so it is also necessary to have dry steam for injectors, air pump, etc. Fig. 228 shows the general arrangement of the dry pipe for this purpose. It will be seen that it takes its steam from the high part of the dome and then passes out of the boiler through a ball joint connection D.

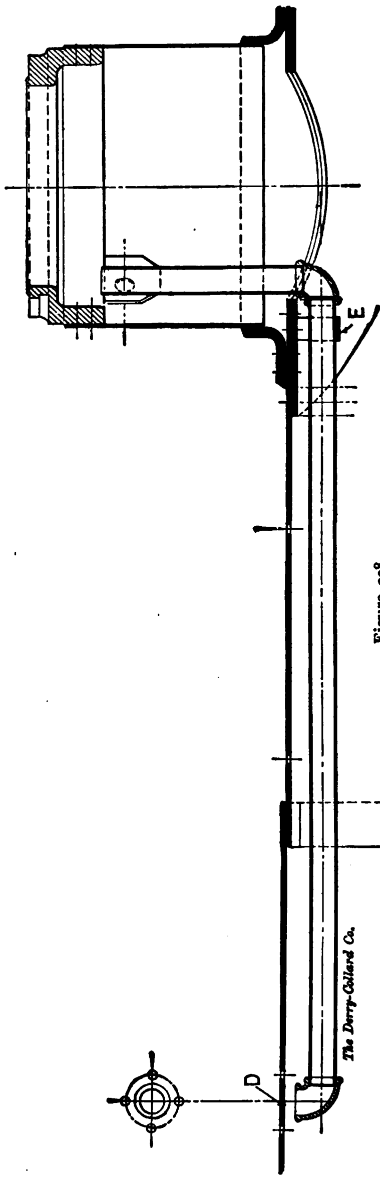

Figure 228

General arrangement of dry pipe.

The pipe is supported at several places by straps E.

The connection from the injector steam valves to the injector and from thence to the injector check is frequently made of copper pipe. The tendency is toward iron pipe due to the expense of copper. The connections when well fitted up to the iron pipes seem to give satisfaction in every way.

Riveted Parts.

In Fig. 229 we see a lapped seam with three rows of rivets R, and staggered between these are three rows

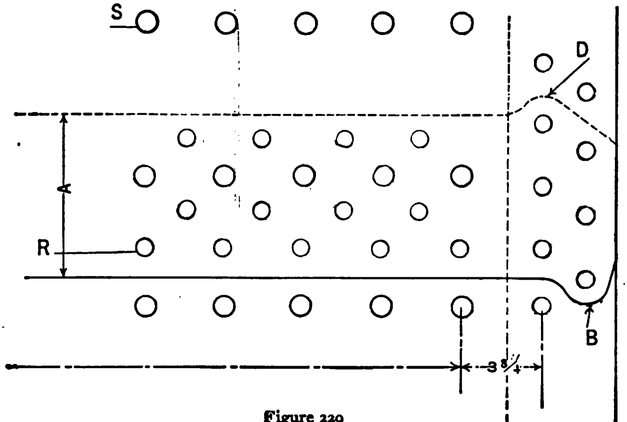

Figure 229
Lapped seam.

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of stay bolt. This is a style of seam which we frequently meet on the outside crown sheet, somewhere along the top sides. The seam is made wide at A, so as to admit of an extra row of bolts as shown. Care must be taken in the laying out and machining of this sheet, on account of the rivet B which comes about on a line with the edge of the sheet. The sheet is bulged out at this point and for this reason we can order a sheet this much longer and then trim the metal away on the inside of the sheet. However, this allowance is not necessary as it is drawn out at this point, wedge shape so as to fit snugly to the sheet underneath.

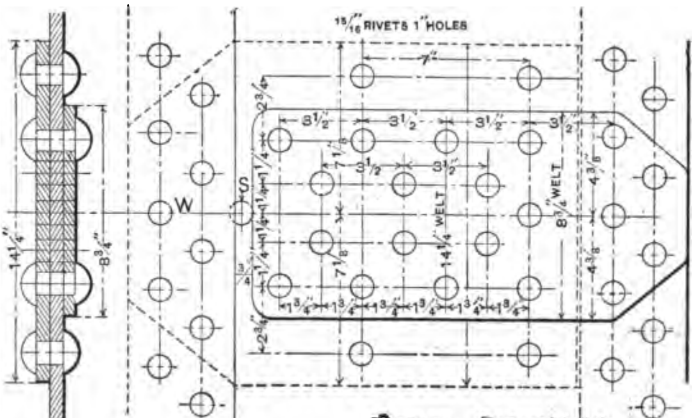


Figure 230 The Derry Collard Co.

Butt seam with welt.

Fig. 230 illustrates a butt seam with outside and inside welt strips. This style of seam is very common on locomotive boilers. This seam is not welded at W, and for this reason a stud S is placed in the seam between the outside sheet and the welt strip. The space between these sheets is only made wide enough to allow calking the sheet. The outside welt strip is always narrower than the inside and is always thicker. This is not only correct for strength, but for calking. A thin sheet with rivets as far apart as here indicated cannot be calked tight.

Many of the connections for the injector check, blow

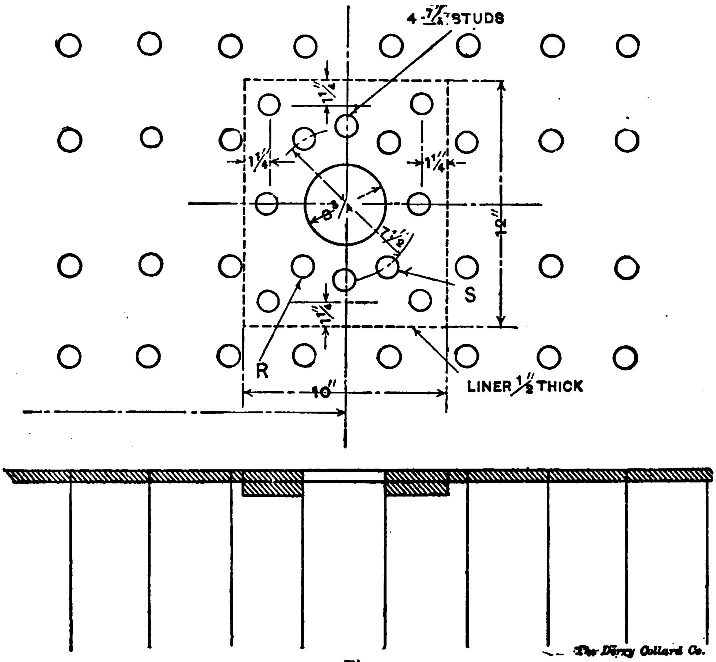


Figure 231

Liner for steam connection.

off cocks, steam valves, etc., are required to be reinforced by a liner. Fig. 231 shows a liner for a steam connection inside of the cab. These liners are riveted to the boiler at R and S and serve a double purpose. They stiffen up the boiler for taps, etc., and compensate to a great extent for the metal which has been removed by the hole. The strengthening of the sheet is a thing which should never be lost sight of.

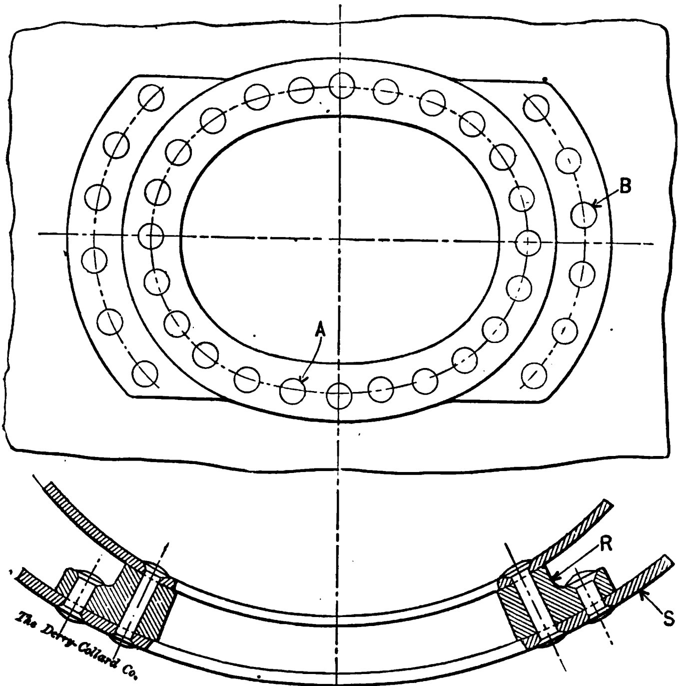


Figure 232

Strengthening a cylindrical firebox.

Fig. 232 illustrates such an example. This is a kind of a mud ring that is used to support a cylindrical fire box. The shell of the boiler S, must resist the bursting strain. As the boiler is very large in diameter, at this section, the

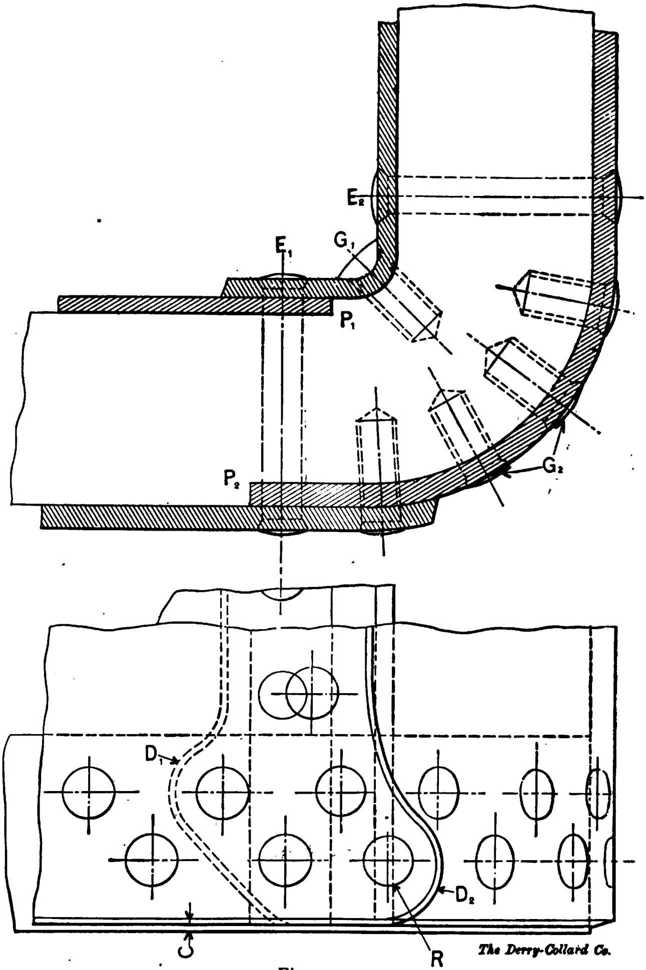
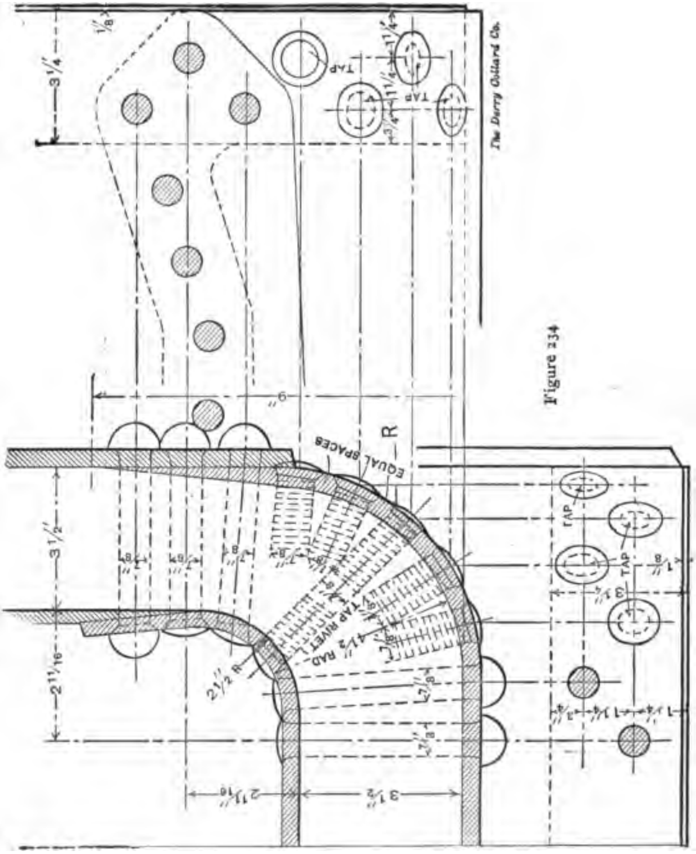


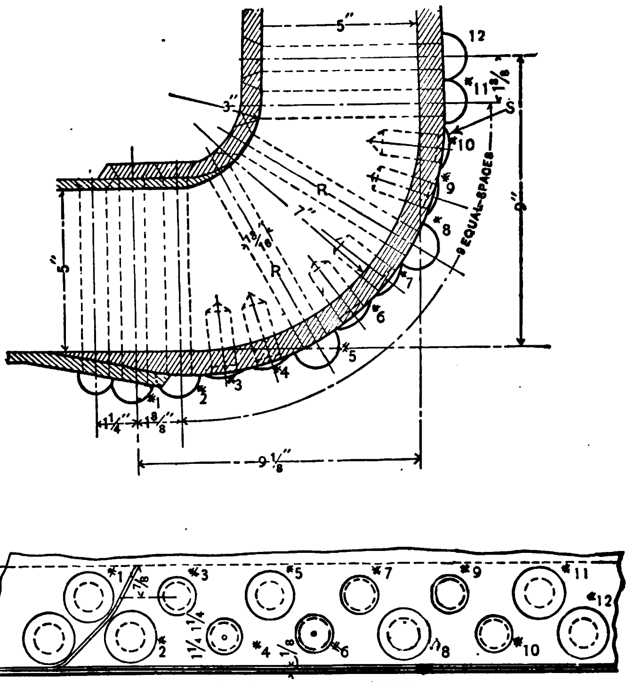
Figure 233

Details of corner of water space.



More details of water space corners.

sheet is necessarily very thick. On account of the weight the stress is somewhat higher in this sheet than in any of the others. It is also seen that an elliptical hole is cut out of the sheet. The ring R must be riveted to the sheet in



DEVELOPMENT OUTSIDE OF CORNER

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Figure 235

Large radius corner of water space.

such a way as to restore to the sheet the strength lost by cutting away the metal. This is done, first by a single row of rivets A, then being reinforced by a second row B on each side, giving the effect of a double riveted joint around the dangerous point of the sheet.

Water space details.

Fig. 233 represents in detail the water space corner, which has been adopted and used for many years as a standard by one of the largest locomotive builders in this country. It shows a double riveted water space frame. The side seam is single riveted and when joining the rivets in the frame, the line of the outside sheet is carried out at D_2 so as to encircle the rivet R. The fire box sheet is swelled out in a similar manner at D, for another rivet. C is usually made a quarter of an inch so as to give a fair chance for calking. The side sheet notches in square at P_1 and the outside sheet is notched in at P_2 so as to allow the other sheet to lap over and thus form a continuous line. E_1 and E_2 are the first through rivets, all the other rivets in the corner are made either of patch bolts or else are studs screwed in, cut off and then riveted over. On account of the small radius on the inside, the rivet has a very small head and for this reason the tap extends through the sheet and into the ring.

This style of corner is good from a manufacturing point of view, but unfortunately, as with all corners, leaks are apt to occur. Consequently, corners of larger radius are frequently specified instead of the sharp corners on the sheet at P_1 and P_2. The sheets are scarfed. Fig. 234 shows such a corner.

It will be seen that the radius of the corner both inside and outside is large and that we have a through bolt R in the corner with a liberal head on the inside. After the ring has been entered into the water space, the scarfed sheets do not fit as they are intended to. So the corner must be heated and the sheet driven against the frame to fit snugly all around. The through holes are then reamed out and tapped holes are drilled and tapped to suit.

In Fig. 235 we have a corner with a still larger radius. The through bolts R and R are riveted in place and have liberal countersunk heads on the inside. The through bolts, it will be noticed, are quite near the corner. The bolts S are studded between the others and are headed up as usual. Sometimes the patch bolts, Fig. 236, are used for the corner of the water space frame. They are screwed snugly into place and then the head riveted down tight.

Although double riveted seams have been shown for

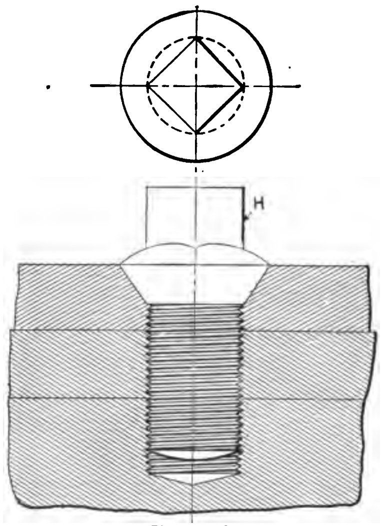
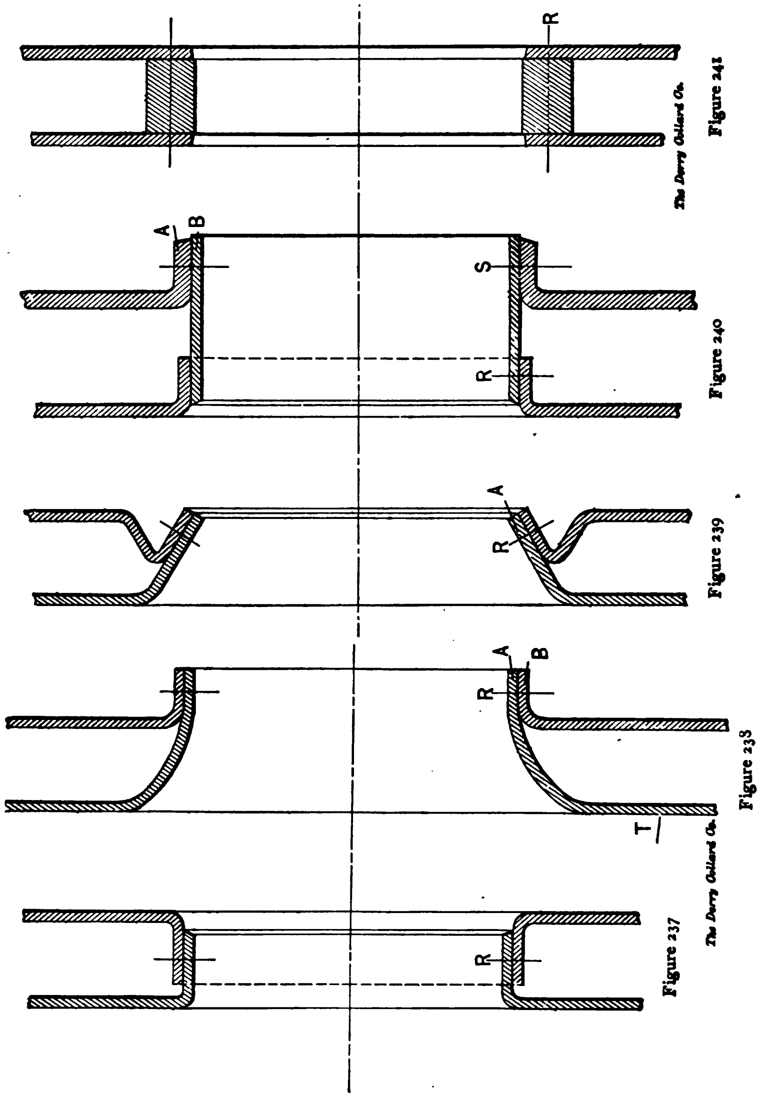


Figure 236.

A patch bolt.

the water space frame in the figures just referred to, single riveted seams are not at all uncommon and on small boilers are nearly always used. The objections to the single riveted frame is not that it is weak but that the seam is more difficult to get tight than the double riveted.



Fire door openings.

When once the seam is calked, a double riveted seam will stay tight much longer.

The usual style for a fire door is illustrated in Fig. 237. The rivets R are placed very close together as the bursting pressure here is very small, and on account of being spaced close together the seam can be calked so as to make a good tight job. These rivets are entered from the inside of the boiler and headed up on the outside by hand.

Fig. 238 shows another style of fire door, which we find on a good many locomotives. The end of the sheet A is either made flush with B and then rounded off semi-circular on the outside and hammered against each other, or else A is made shorter than B and is calked against B, so as to form a tight seam. The rivets R, in this case, are through rivets and can be put in by machine, instead of being hand driven as in Fig. 237.

The sheet T is usually 5/16 to 3/8 of an inch thick but when it is flanged out as indicated, it becomes very thin at A. This is objectionable and for this reason we find fire doors like Fig. 239. The edge at A is made tight in exactly the same way as in Fig. 238.

A different style of fire door is obtained by a ring B, Fig. 240. It is let into the sheet as indicated. The rivets R are driven by hand, while S can be driven by machine. The sheet at A is made 1/8 of an inch less than B for calking. The fire door ring is resorted to, although not as frequently as a few years ago. As very little strength is required in the sheet along the fire door, the rivets can be placed in a single row and spaced close together. The ring projects in the inside for a short distance so as to furnish a calking edge.

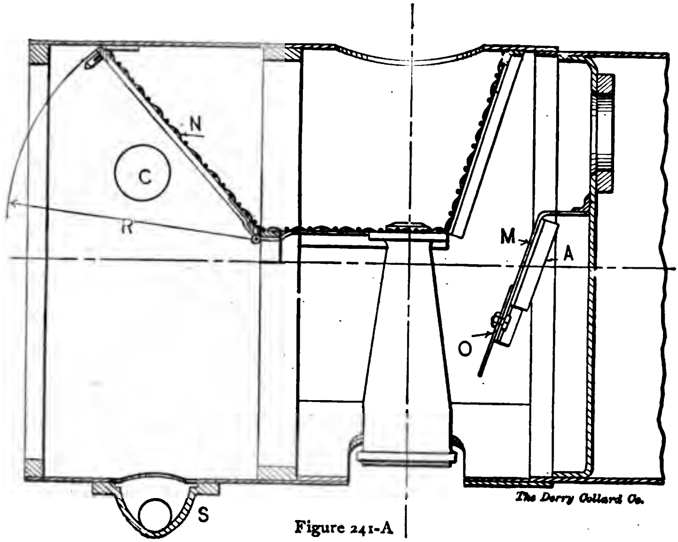


Figure 241-A

Arrangement of front end or smoke box.

Smoke Box Details.

It is next to impossible to get an even flow of gases through all the tubes of a locomotive boiler and for this reason all sorts of deflecting plates have been used. The one which perhaps answers the purpose as well as any and which is very generally used is illustrated in Fig. 241-A. M is the stationary plate. It is made in two pieces which are joined on the center line of the boiler. The work of fitting these two pieces around the plates and along the side of the boiler is much reduced by having the sheets in two pieces. The piece is slipped in place and then a scriber is run along the edge, thus marking off a constant distance for offsets and so on.

Netting for spark arresters.

The sheet is then taken out and the metal is sheared, drilled, or punched away to this line, after which the sheet is replaced and will fit snugly to the side of the boiler. The other side is fitted up in the same manner. A is an angle iron which supports the sheet on the sides.

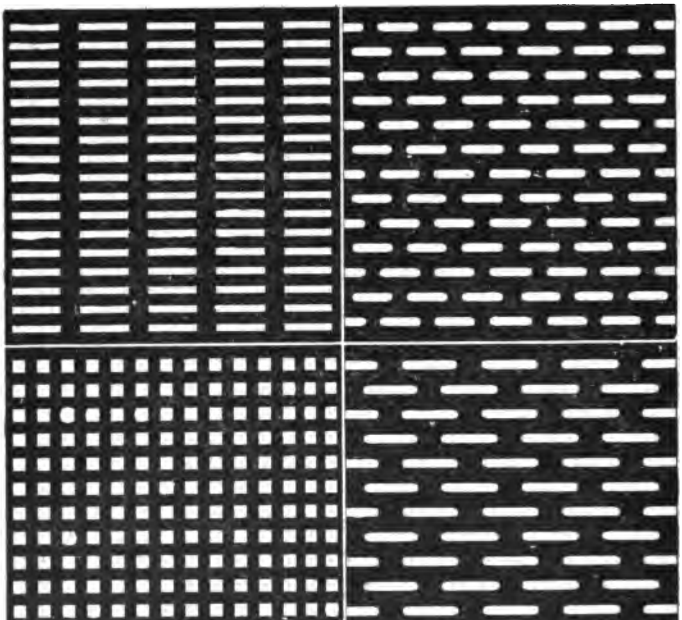


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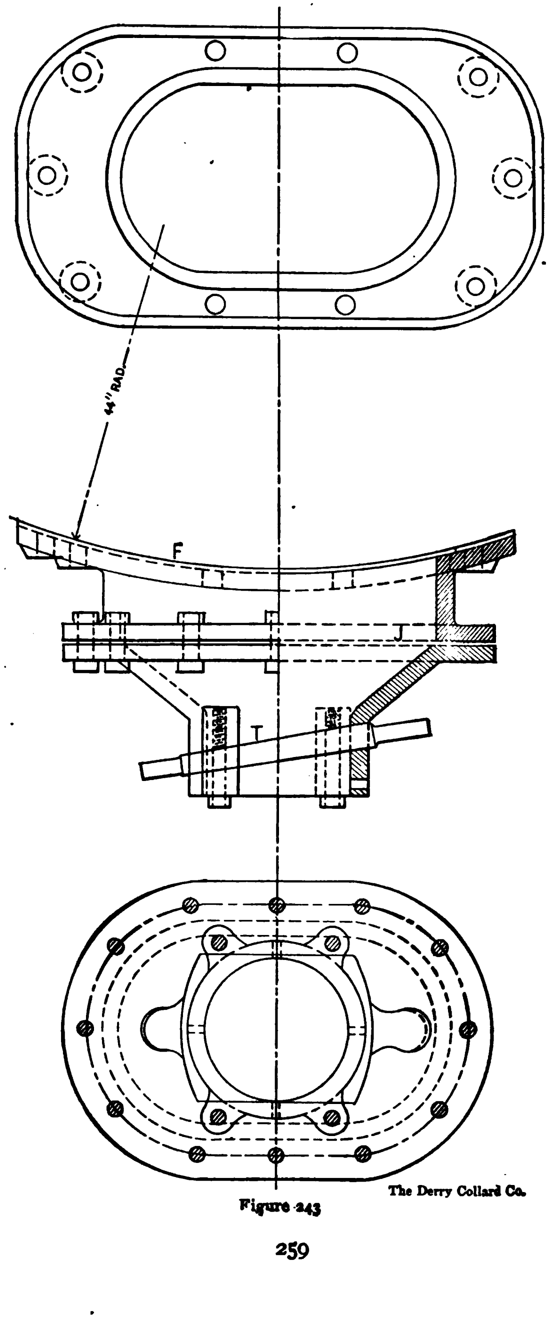
Figure 242

Perforated netting used in smoke box.

O is the slide which has an adjustment up and down about half its width and must be cut off on the sides so as to clear the boiler in its lowest position.



Cinder pocket for cleaning out front end.

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Figure 243

The netting is also shown in this figure. It is held to the sides by angle irons and is hinged in front at N. This hinge can be dropped down and everything cleared out from the front. R must be such that the door will clear all around. C is a cleaning hole and S is a cinder pocket. The size of the netting which is used in the smoke box depends upon the kind of material and the

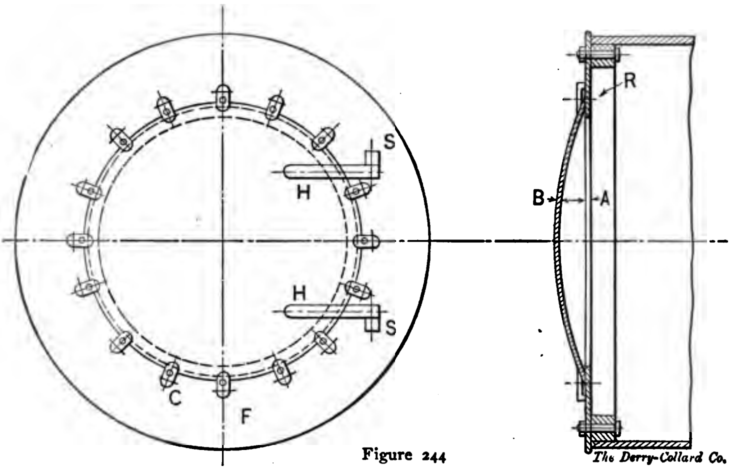


Figure 244

Front end of boiler.

conditions surrounding the railroad where the boiler is to be used, such as fuel and country run through.

Sometimes the netting is made of wire which is woven into square meshes, two, three or four to the inch, but frequently they are made of perforated plates and then the holes are punched like some one of the styles shown in Fig. 242. These plates can be shaped in any form and punched with a margin. But much the cheapest job, and one which is satisfactory in every way, consists in buying the sheets all punched and then trimming off to fit into place the same as netting. The pieces cut off can be used for patching in corners on the job.

The cinder pocket is arranged in many different

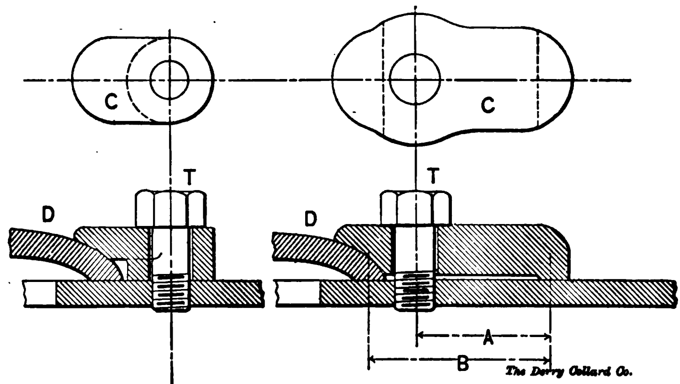


Figure 245 Figure 246

Clamps for front end door.

ways, either to be cleaned by hand or by a jet of steam, although the former is the more frequent. In Fig. 243, a cinder pocket T is shown. The slide fits in snugly all around so as not to admit any air, and for this reason the slide should always be planed. The cap C is bolted on and admits of a plain surface on the body and the cap. The upper part of the pocket is bolted to the boiler by studs. These holes must be vertical and the studs must be screwed into place. Then the hopper is entered over the studs and bolted up solid. The chipping strip should be chipped to fit the boiler.

The front end of a locomotive boiler is shown in Fig. 244. A is a piece of boiler plate turned on its outer edge and bolted to the ring R which is faced off on the outside to receive it. B is the front door. This is flanged out spherical in shape and turned off so as to fit against the plate. The door is supported by strap hinges H and studs S. A lot of clamps C are used to keep the door tight against the front sheet.

One of these clamps is shown at C, Fig. 245. They are made of drop forgings, and although they do not give a very good clamping effect they are very readily removed from the door. A quarter turn of the bolt T loosens the clamp and, the base being round, the clamp will swing

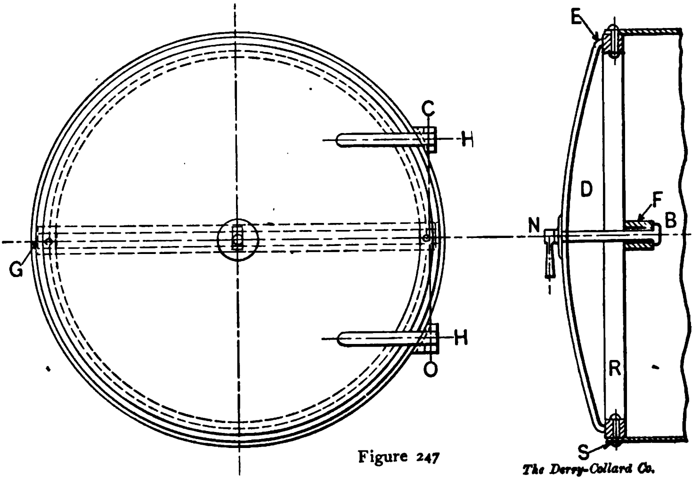


Figure 247

Smoke box front door.

out of place. A much better clamp is shown in Fig. 246. In order that a bolt may clamp properly the distance A should be large, which would bring the bolt very close to the door. If the difference between A and B is small, we get almost the whole effect of the bolt. Although this is a much better clamp than the one shown in Fig. 245, it is not so conveniently removed and put back into place.

In Fig. 247 we have a smoke box front door which is being used quite a good deal in this country and which has been used for a number of years abroad. It is a much cheaper door to make in quantities than the one illus-

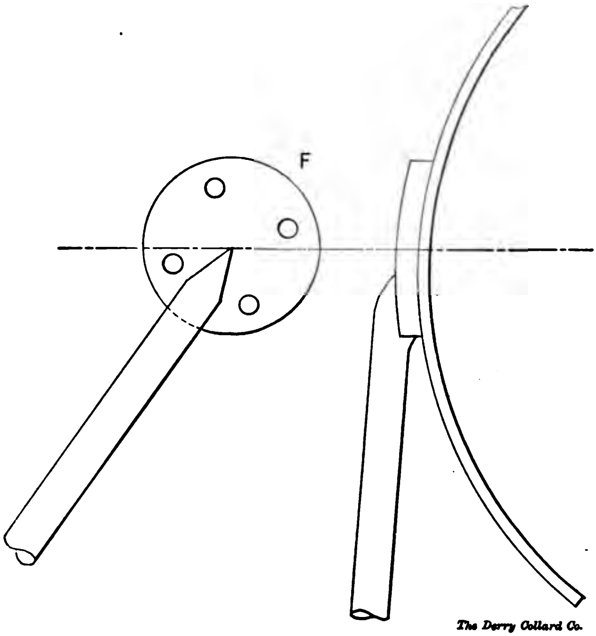


Figure 248

Smoke box brace.

trated in Fig. 244, and much more readily opened and closed. The door D is flanged spherical with a small radius at E then turned off smooth, as is also the face of the ring R. B is a T head bolt which, when turned

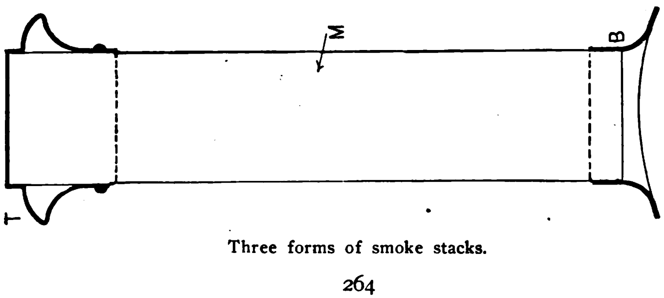


Figure 249

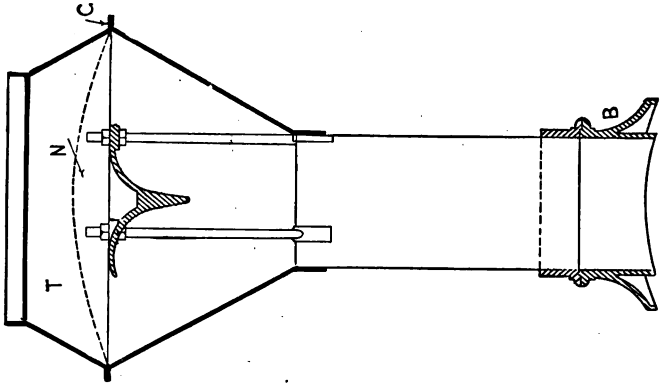


Figure 250

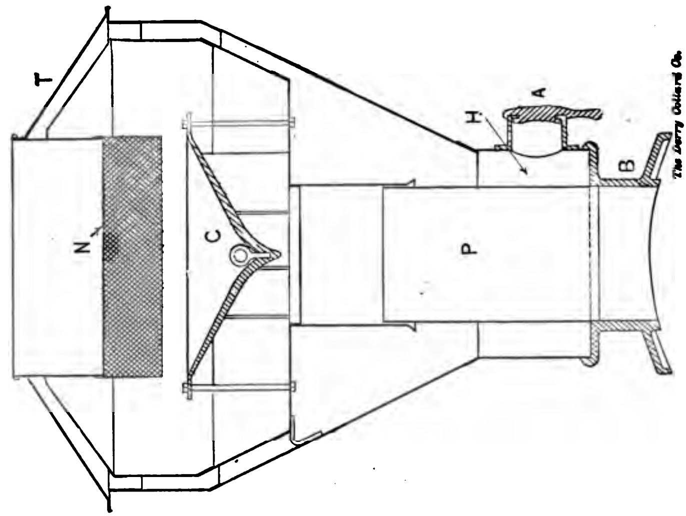


Figure 251

Three forms of smoke stacks.

through 90 degrees, will pass through the wrought iron strap F. GG are filling in pieces for keeping these straps the proper distance apart and are bolted to the ring. N is a handle for clamping the door. The outside sheet must be tight at S and for this reason the ring is allowed to project 1/8 of an inch and the sheet is calked.

The smoke box brace, Fig. 248, is forged under the steam hammer and however well it may be shaped the foot F will not fit the boiler at the first trial. For this reason the foot is heated and the brace is brought to the boiler, held up in position and hammered back so as to fit up against the boiler all around. In Fig 249, a common form of smoke stack is shown. The base B is square where it fits to the boiler and is flanged out to suit the stack. T is frequently made of copper, while the main part of the stack is made of sheet iron. This stack is a plain opening without any netting. Where sparks are objectionable the stack, Fig. 250, is used. N is a netting which is screwed to the flange sheets at G. C is a cast iron deflector. When the sparks come up through the stack they hit against C and are deflected and either go out of the stack slowly or else fly around the inside and gradually fall back into the smoke box. The base B is made of cast iron and is chipped to suit the boiler. Fig. 251 illustrates a stack which is intended to keep all sparks from being thrown out.

The base B is made of cast iron and is chipped and bolted to the boiler. The steam and sparks come up the pipe P, strike against C and are deflected by it. The sparks then have a chance to drop down on the inside of the pipe and collect in the hopper H from which they are removed through a hand hole A. N is a netting of a very fine mesh.

Boiler Fittings.

The steam connection of the injectors is coupled to a steam valve S, Fig. 252. This steam valve is connected to the dry pipe D which leads to the dome. H is the handle for regulating the flow of steam.

A check valve such as should be placed between injector and boiler is shown in Fig. 253. The flange F is made of brass and is riveted to the boiler as shown. It has a taper tap at T. P is a plug with a leather gasket underneath it and can be taken out to renew or for regrinding the valve. S is the pipe that leads from the injector.

In order to regulate the flow of water to the injector, it is necessary to have a valve, Fig. 254, placed in the pipe. The handle H can be made of metal as this valve rarely gets hot. P and P are pipes whose inside diameter should be equal in cross sections to the pipe specified by the makers of the injector.

A blower valve is represented in Fig. 255. As it is not necessary to have perfectly dry steam, it is tapped into the boiler with a taper thread at T. P is a blower pipe and H the handle for controlling the flow of steam.

Fig. 256 represents a sectional view of one of these blower valves. The stem S has a screw on it as shown and the end being long, any slight eccentricity can be offset by the spring. This style is made by numerous manufacturers and must be attached to the boiler by means of a pipe nipple.

A whistle valve is seen in section in Fig. 257. This is one of the balanced type and does not require the dead

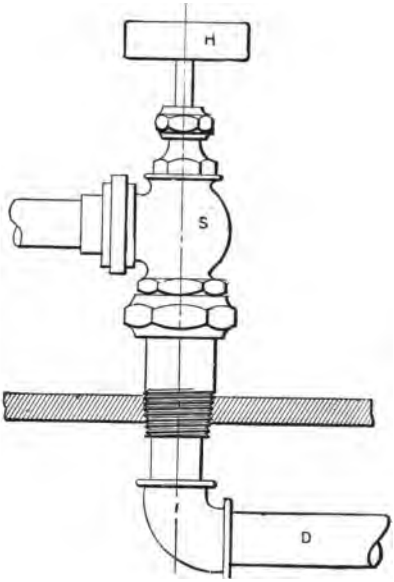


Figure 252

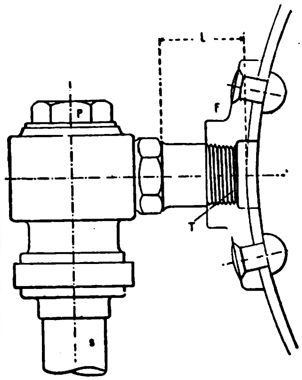


Figure 253

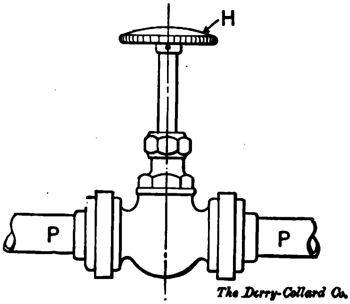


Figure 254

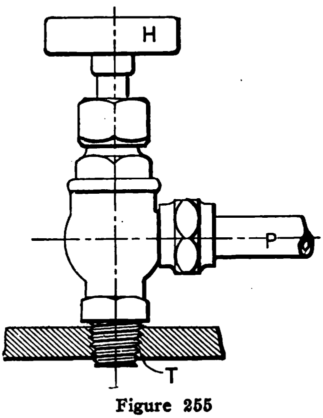


Figure 255

Boiler fittings—stop and check valves.

pull on the end which is so frequent with unbalanced valves.

Nearly all boilers are now fitted up with safety plugs in the crown sheet. They are made of composition which melts at a temperature somewhere around 500 degrees Fahrenheit. An outside type of one of these plugs is

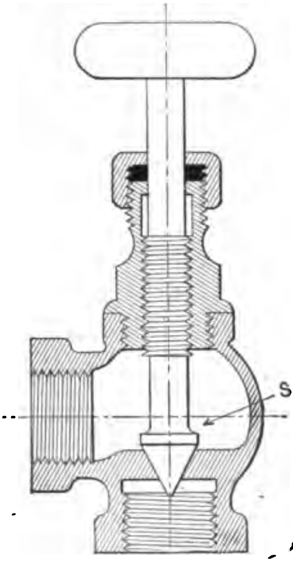


Figure 256

Blower valve.

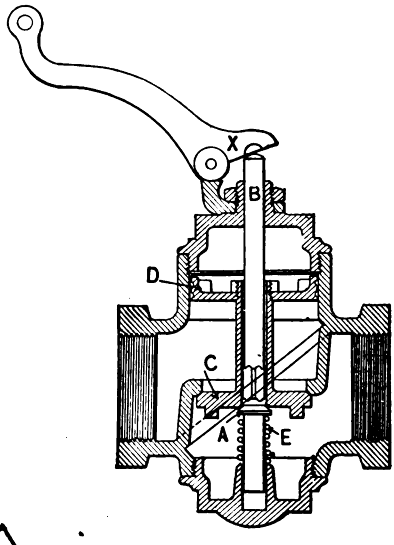
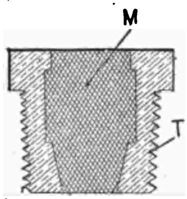


Figure 257

Whistle valve.

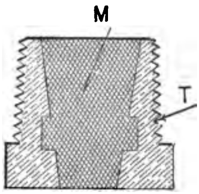
seen in Fig. 258. T is a taper tap which taps directly into the sheet. M is the composition metal. The inner surface of this plug is tinned and the metal M is sweated in solid so that the core does not need to be calked to make it tight.

Fig. 259 represents an inside type. Hexagonal heads are provided for screwing them into place. On account of the great accumulation of mud in the water space, several blow off cocks, Fig. 260, are usually specified. The taper tap T enters either directly into the sheet or else is tapped into a flange which in turn is riveted to the boiler. The central portion is tapered at



Outside Type

Figure 258



The Berry Collard Co. Inside Type

Figure 259

Fusible plugs.

A and is ground in-with powdered emery so as to have a perfect bearing. C is a core hole through the center and when the cock is turned at right angles to the position shown, a straight passage is opened for the steam through D. It is shown closed.

When the water is very muddy and cleaning pipes are used, they are supported on studs S, as in Fig. 261. They have a tapered tap at T and the sheet is tapped so that the threads will be tight, just a little before the head touches the sheet. They are placed close to the bottom of the water space so as to draw as much of the mud as possible out of this space.

Nearly all boilers are fitted up with glass gages, so as to show the level of the water, although on account of foaming and mud collecting on the glass they are not de-

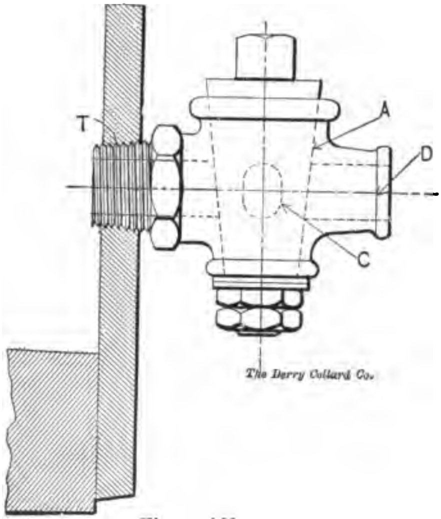


Figure 260

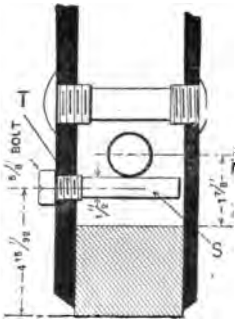


Figure 261

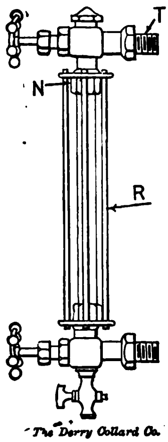


Figure 262

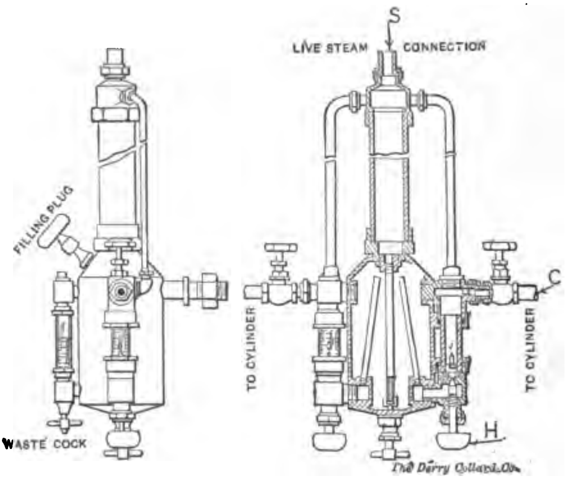


Figure 263

Blow off cock—water glass and lubricator.

pended on as a sure indication of the height of the water. Three gage cocks are usually supplied, covering a range of a few inches, around which the water should be kept. A form of water tube is illustrated in Fig. 262. The fit-

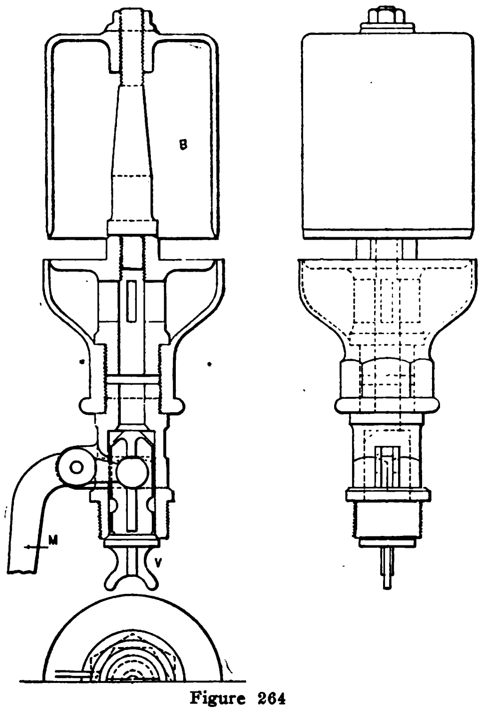


Figure 264

Construction of whistle.

tings top and bottom are screwed into the boiler by taper taps T. The nuts N are placed upon the tube and the tube made long enough to go between these fittings. These nuts have packing squeezed into them after which they are screwed up into place. R are rods to protect the glass from accident.

The modern tendency is to furnish a never failing supply of oil to the cylinders, and a number of lubricators

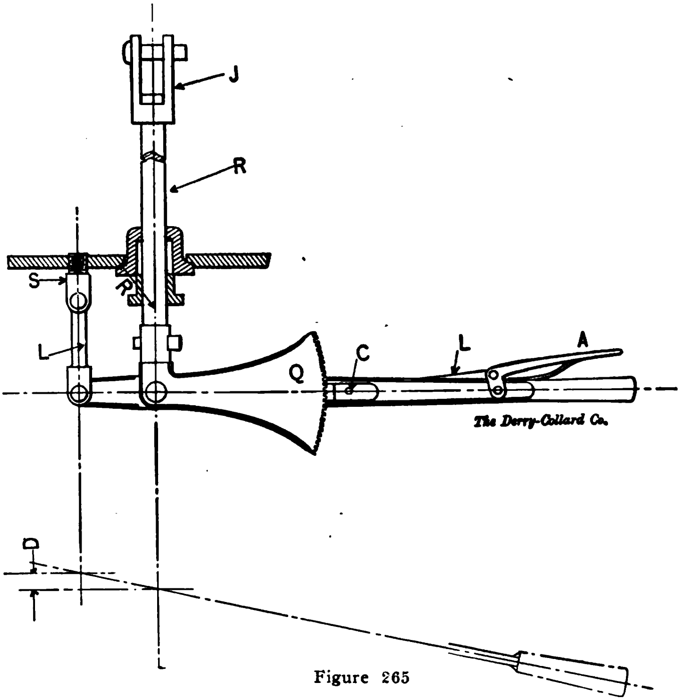


Figure 265

Throttle lever arrangement.

have been placed on the market for this purpose. In Fig. 263, is shown a side and a section view of a Nathan lubricator. S is connected to a steam pipe. C and C lead to the cylinder. The handles regulate the flow of oil, which can be seen through the glass on each side.

Boiler fittings.

Fig. 264 represents a whistle with a valve connection all complete. This whistle is either screwed into the dome cap or is screwed into an elbow which runs into the side of the dome. V is the valve. M is the bell crank for operating the valve. B is the bell of whistle.

A common arrangement of throttle lever is illustrated in Fig. 265. The rod R passes through a stuffing box in the back head, and extends on through and connects to the bell crank of the throttle by means of the jaw J. S has a taper tap and forms a support for the link L, the quadrant Q is keyed to the rod as indicated. In this construction we have the floating lever principle, and the rod moves in a straight line while the link L takes care of the curvature. The catch C is lifted from the quadrant by pressing A to the handle. By releasing the handle, it can be held in any position. The figure D is given on the boiler card or the erecting card and upon it depends the location of the handle.

Assembling and Calking.

Assembling.

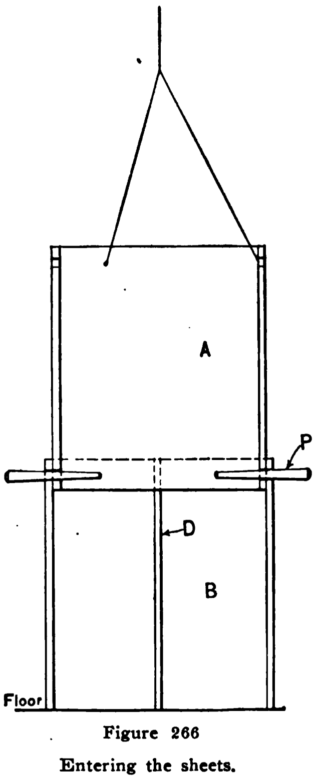


Figure 266
Entering the sheets.

The method employed in entering the cylindrical sheets into each other is seen in Fig. 266. The sheet A is raised up by a crane and is then lowered inside of B. A wedge is driven between the edges at D and the lower course is entered up. These sheets are not always a perfect cylinder, consequently they do not go together as easily as one might suppose they should. After the sheet A has been entered into B, it is twisted around so as to bring the corresponding holes vertically in line. A taper pin P is then entered into the hole and driven in. Several other pins are entered at different places and also driven home. It is not a good thing to use these drifts but under the circumstances this is the only way we have of bringing the holes directly opposite each other. The evil caused by driving these pins into holes in

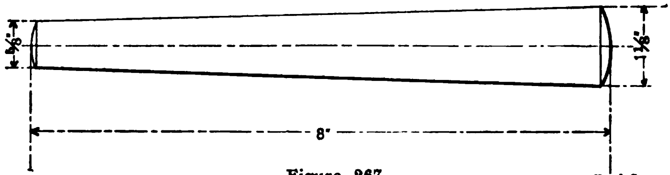


Figure 267

Drift pin.

order to open them up, is too well known to require special mention. If care is taken in laying out and punching the holes, these drift pins need very rarely be used.

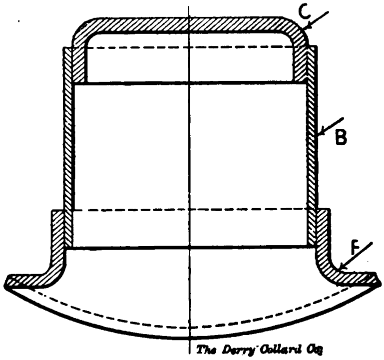


Figure 268

Assembling dome.

While the sheets A and B are supported by the pins P, bolts are entered into some of the holes and the sheet is drawn up as tight as possible. After this the welt strips can be put in place and also bolted up. These sheets can now be riveted. One of these pins P is seen in Fig. 267. The size depends upon the size of the holes. For inch rivets a pin with these dimensions answers the purpose very well. They are made of tool steel and should be turned rather than rough forged.

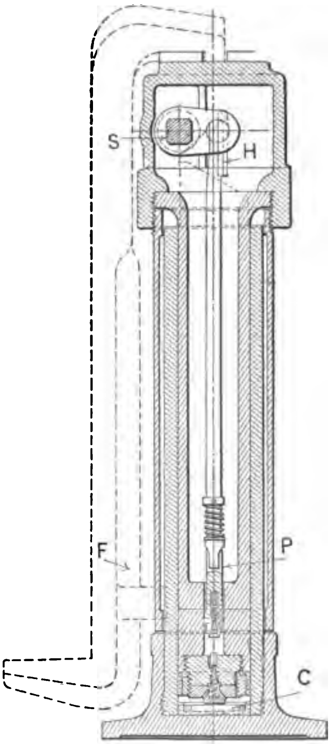


Figure 269

Hydraulic jack.

In Fig. 268, B is the welded body of a dome. In entering the cap C into this dome a tight fit is required. The domes are all welded to a given diameter and the cap C is turned off on the outside a little larger in diameter. The body of the dome is then heated and the cap is entered into it. The holes are then straightened up by means of tapered pins, Fig. 267, and a few bolts are put in to keep the cap in position. The dome flange F is now heated and the body of the dome is entered into it and twisted around so as to line up with the proper holes. A few bolts are also put in to keep the flange in place.

In assembling the various parts of a locomotive boiler and where adequate crane service is not to be had, hydraulic jacks, similar to Fig. 269, are very convenient. This illustration shows a cross section of the jack. The shaft S has a handle attached to it and when it is moved up and down the plunger P is raised and lowered. On the lower end of this plunger is a valve which allows the liquid to pass downward through it but checks it from returning. At each stroke, some of the liquid is pushed down into the chamber C. This liquid, being forced in here under a pressure, acts upon the diameter of the main piston and forces it upward, thus raising the boiler. When it is desired to lower the boiler a handle H turns, which releases the valve at the lower end of the piston P. The liquid then rushes back through the valve but on account of the small port opening, the downward motion is very gentle.

A steel foot F hooks over the top of the jack and is very convenient for getting under the water space and other places which are close to the floor.

In handling a boiler with a crane, ropes, Fig. 270, are

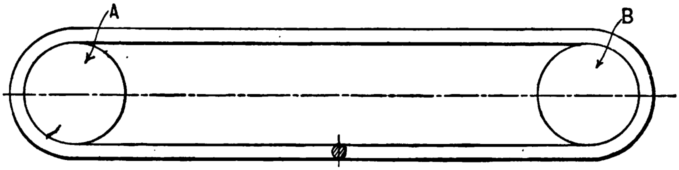


Figure 270

Ropes for handling boiler.

convenient, in addition to the usual run of chains which are frequently used. They are made of different lengths of tar rope. It is wound round and round the pulleys A and B until the required number of strands are obtained. It is then covered with heavy canvas cloth, then wound on the outside, binding the whole thing into one solid cable. Several of these ropes are always kept on hand and are used to lift the boiler as shown in Fig. 271. H and H are two double crane hooks. The rope is long enough

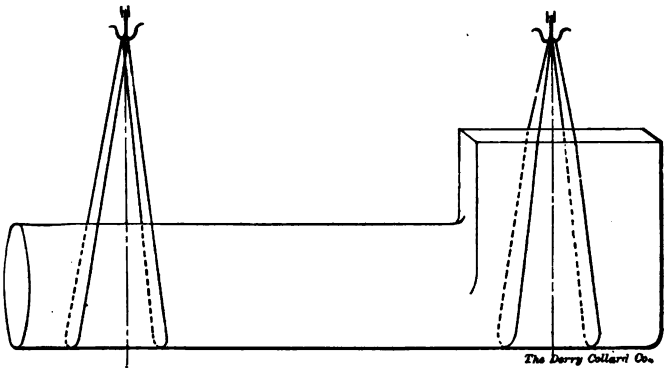


Figure 271

Slinging boiler with ropes and crane.

to reach around the boiler and then is dropped over the hook as shown. These ropes are very strong on account of the equalized pull that is brought upon each of the single strands of the rope. Another good point is, that they will never mar the boiler plate as is so apt to be the case in using chains.

The usual method of attaching the sand box to the boiler is illustrated in Fig 272. The feet L are made long so as to chip on boilers of various radii, between certain limits. The base D is made of cast iron; it is set upon the boiler and lined up with the center line. A scriber is then run along the boiler and the feet are marked off at an equal distance all around in order to give each foot a bearing. The base is then taken from the boiler and the feet are chipped off at this line. The base is held to the boiler by two studs which go into taper holes into the sheet, and nuts on top to receive the base D.

The body of the sand box B is made of wrought iron. The seam is riveted with a single strip on the inside and

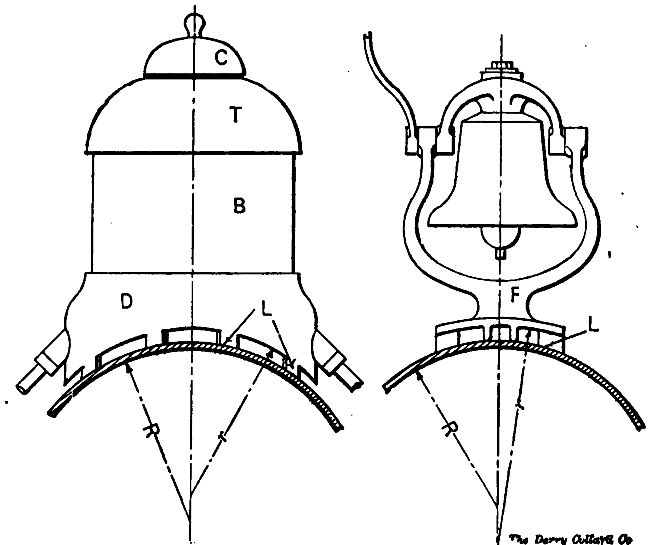


Figure 272 Figure 273

Attaching sand box and bell.

the rivets countersunk flush on the outside. The top T and the cover plate C are made of cast iron.

The base of a bell, Fig. 273, is chipped to the boiler in a similar manner as the dome. The feet are made about one inch long and will fit almost any boiler by chipping to suit. The bell is usually held by two studs on the top center line, one front and one back.

Calking.

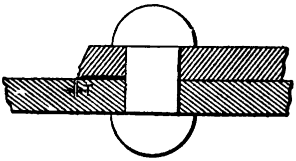


Figure 274

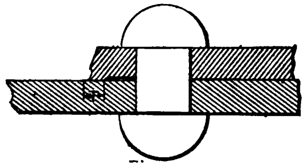


Figure 275

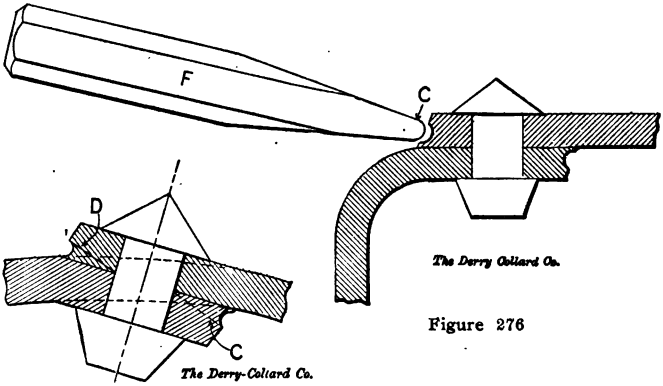


Figure 276

Figure 277.

Calking details.

Calking.

No matter how much of the best labor has been expended on a locomotive boiler, its final success depends upon the calking it receives. Many a poorly calked boiler has been hurried off to the erecting shop and then when the water pressure was turned on another hurry up job was made calking the leaks. The lagging was put on and the sheet iron covering, everything painted and polished up and the locomotive shipped. A few days later a letter comes to the office, stating that the boiler must be stripped and every seam thoroughly calked, which of course is at the expense of the builder. After such lessons, one cannot help but realize the importance of a well calked job before it leaves the boiler shop.

Too frequently the calking is only done as indicated in Fig. 274. The metal has been calked down so as to be tight against the sheet but only for the small distance T. When the boiler is racked and strained in service, this small thin strip becomes loose and we have a leaky seam. If, however, the calking tool is pounded more firmly into the sheet, we get an amount of metal, Fig. 275, much greater than before, making a solid connection between the sheets. The amount of contact, or of distance T, is what makes the calked edge good or bad.

A calking tool is shown at F, Fig. 276. It consists of a hexagonal piece of tool steel, drawn out and rounded off at the end C, as indicated. This illustration also represents a section through a fire box seam and these seams calked inside and outside as indicated. The edges of the sheet should be beveled off as shown.

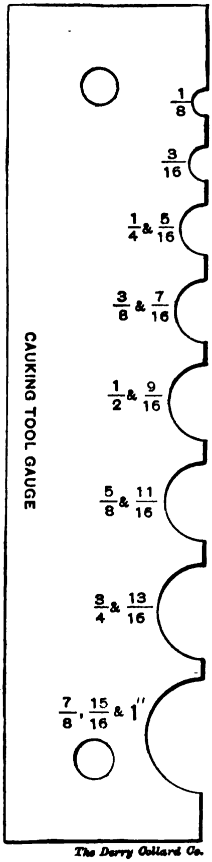


Figure 278

Calking Tool gage.

In Fig. 277, we notice a single riveted seam which has been calked inside and out. The metal at C and D is calked tight enough to form perfect contact from

the outer edge of the sheet in as far as the rivet.
A gage for the calking tool is represented in Fig. 278.

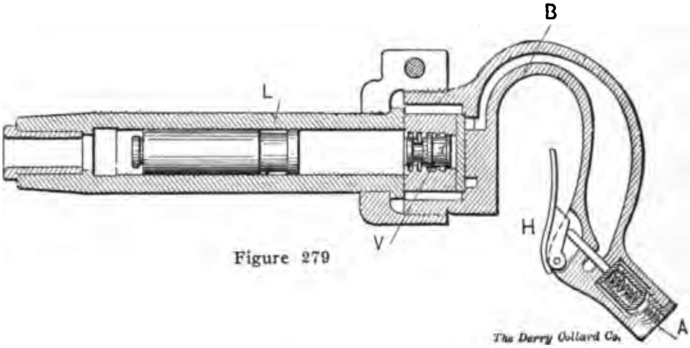


Figure 279

Pneumatic hammer.

The different notches are marked with the figures which represent the thickness of the plate for which a tool

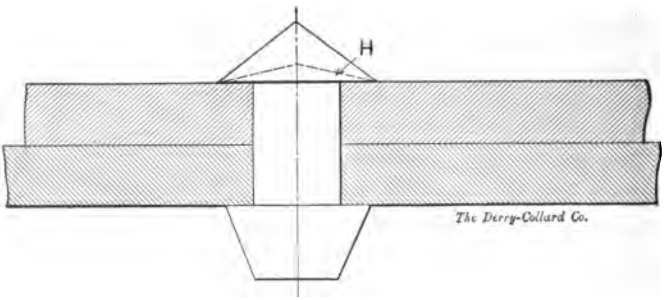
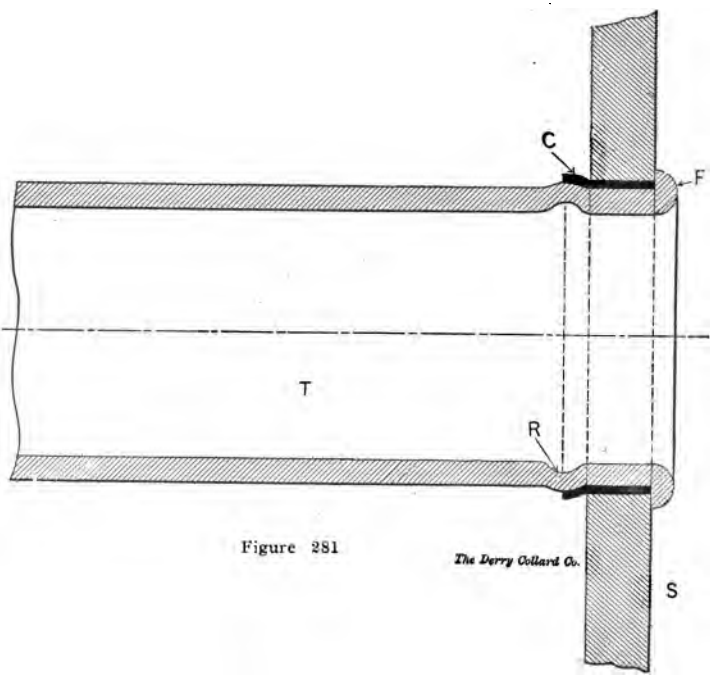


Figure 280

Not a strong head.

shaped to this gage should be used. In some locomotive shops a strict adherence to this gage is insisted upon, which is a wise plan to follow. These gages are made of steel and are about one-eighth of an inch thick.

A cross section of an air tool used for calking is shown in Fig. 279. The heaviest style of such tools give the best satisfaction, as it is not light blows but heavy ones



Boiler tube rolled in place and calked.

which give the best satisfaction in this work. The air enters the hammer at A when the handle H is pressed down, the air rushes around the chamber at B and passes through the valve V, driving the hammer down against the calking tool. Three to nine hundred blows per minute, depending upon the length of the stroke, can be obtained with one of these hammers. It is not only the seams that leak. Each one of the rivets must be calked, with a much sharper tool than that which is used for the seam. This is a tedious process and requires a great deal of time. It is during this operation of calking that the flat heads, Fig. 280, are disliked. A head of this shape is neither a satisfactory job for strength nor calking. The head should be shaped as indicated by the dotted line. This gives a fair rivet and a much better job to calk.

In addition to calking the seams and the rivets, the boiler tubes must also be calked and also any other fire tubes, fire brick tubes, etc., which may be used about the boiler.

In Fig. 281 T is the rear end of a tube, S is the tube sheet, and C the copper ferrule. This is a very common construction for boiler tubes. On account of the expansion of these tubes, the inside portion at R is expanded so that the tube is hooked around the tube sheet

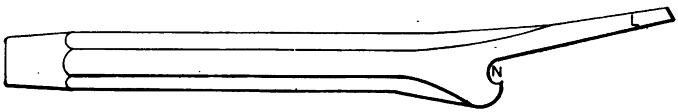


Figure 282

Tool for calking tubes.

and this not only resists a thrust in one direction, but in both. After the sheet has been expanded out against the copper ring and also at R the end of the tube F is calked over. This is very nicely and rapidly done by a compressed air hammer, Fig. 279. The calking tool, Fig. 282, has a semi-circular nose N which fits over the tube at F and a leg L which enters the tube and rests against the side wall.

Fig. 283 is a cross section of an expanding tool. This tool is driven by a ratchet handle H and can be used in corners where only a slight motion of the handle can be obtained. It is fitted with a taper pin P, which ex-

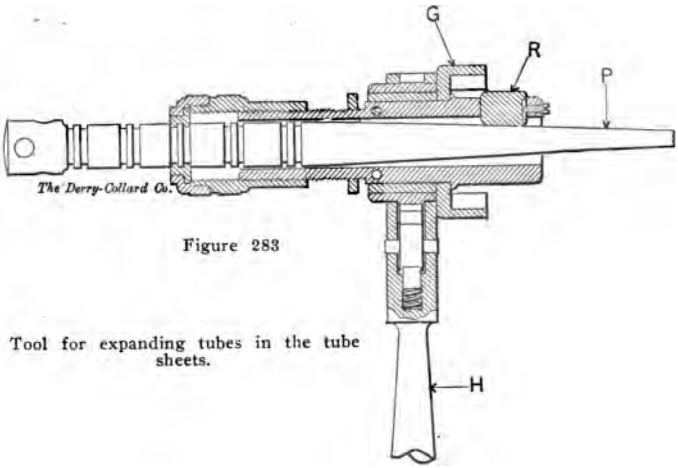


Figure 283

Tool for expanding tubes in the tube sheets.

pands the three rollers R. G is a guide which serves to keep the expanding tool straight. As P is forced in, the rollers are pushed out in order to accommodate a larger diameter.

A somewhat different construction of tube is illustrated in Fig. 283. The end C is made of copper and is sweated or brazed on the end of the copper along the line J. The thread portion T of the tube is screwed into the sheet S and the tube is flanged over at F as in the previous case.

The general construction of the fire tubes is shown in Fig. 284. S is the fire box sheet and T is the outside sheet. The tubes are swaged down on the fire end and

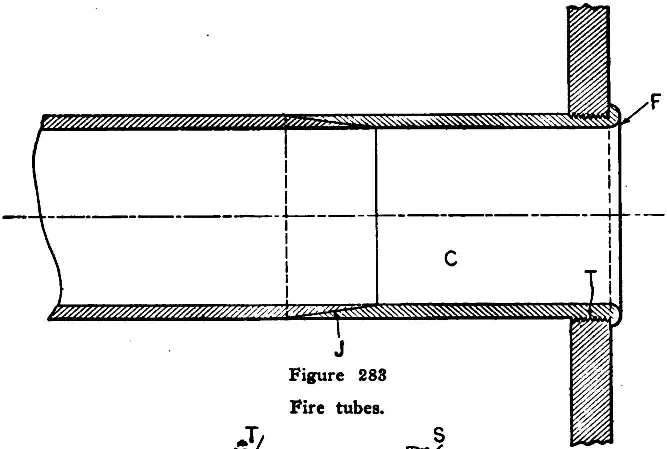


Figure 283

Fire tubes.

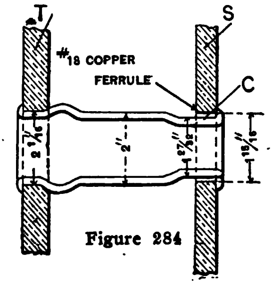


Figure 284

Fire tube construction.

entered into place with a copper ferrule C as represented. The tube is expanded in the same way as a boiler tube and then the outer edge is beaded as in this illustration.

The usual construction of a fire brick tube is seen in Fig. 285. They are bent to the required shape before being entered into the sheet, the hole H being large enough to admit of this operation. The tube is then expanded against the side of the hole and the outer edge of the tool is flanged as seen in this figure. The small diameter of the plug D clears the largest portion of the tube E, by ⅛ or ¼ of an inch. H is a hexagonal core into the back of this plug for the purpose of screwing it into place.

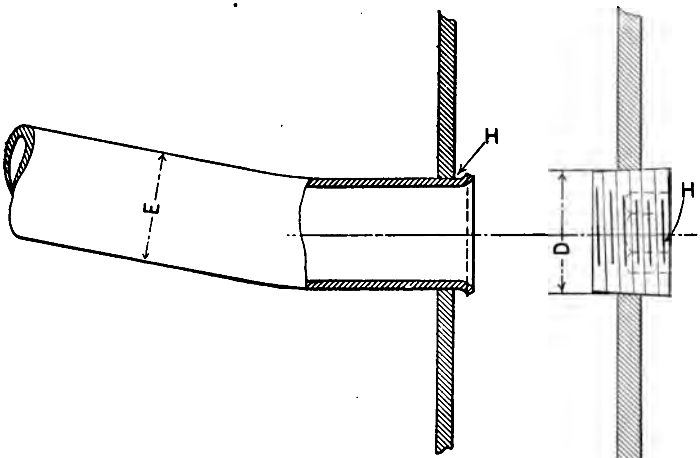


Figure 285

The Derry-Collard Co.

Fire brick tube construction.

In riveting up the ends of the stay bolts and in calking them tight to prevent leaks, it is a decided advantage to have the bolts cut off to the same length. For this reason the stay bolt cutter or nipper, Fig. 286, is now being used by some of our builders. This machine is operated by compressed air and cuts all the bolts to the same length.

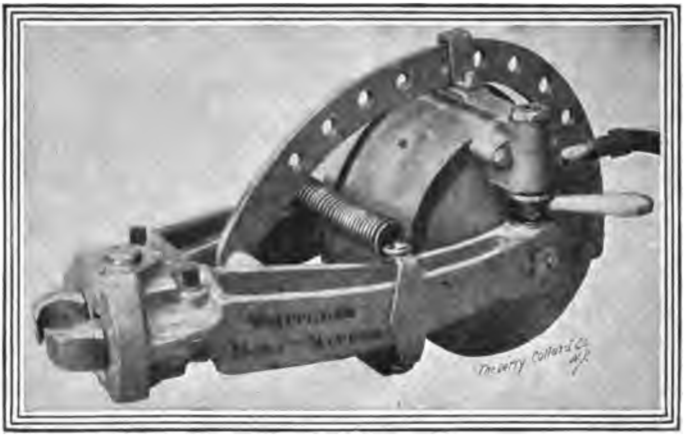


Figure 286.

Pneumatic stay bolt center.

Finishing Parts.

After all the work has been done in the boiler shop, the boiler is carried by a truck or crane and raised over the partially erected locomotive, to which it is to be fitted. It is now lowered and shifted forward and backward in order to locate the proper distance from the throat sheet to the cylinder center. It is then lowered upon the cylinder and the flange scribed so as to make the correct distance from the cylinder center to the boiler center. The boiler is then removed and the cylinder saddle chipped out to the line which has just been scribed.

As the amount of metal to be removed varies anywhere from ⅛ to ¾ inch, three or four men are put to chipping in order to hurry the job along. To keep the flying chips from injuring the workmen, a piece of canvas A, Fig. 287, is thrown over a support B.

After the cylinder saddle has been chiped off evenly to the straight edge, the boiler is put back in place. The

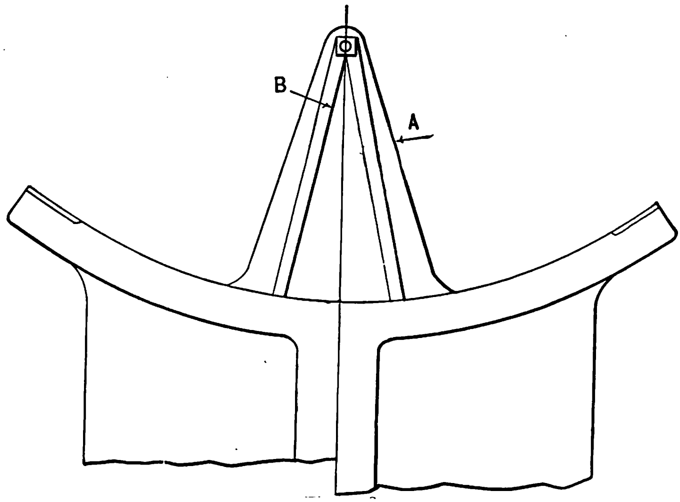


Figure 287

Protection while chipping cylinder saddle.

holes for the cylinder bolts are then drilled and reamed out and the furnace bearers are marked off and drilled. The boiler is then raised and a mixture of red lead laid over the top of the flange. The boiler is then lowered into place, the bolts are entered and drawn up tight. The tubes are now entered through the front door and pushed into place. On account of the variation of the front and back tube sheet from a plane surface, the tubes are not all of the same length.

For this reason, a pole is placed through a set of tube holes, the length is noted. All the holes are thus measured up and a chalk line is drawn on tube sheet so as to enclose all the tubes of the same length. A half dozen different lengths will ordinarily be sufficient. The tubes are then entered into their proper places and expanded and beaded.

The side frames for grate are now bolted into place and the shaking and drop plate levers attached to the boiler. The cab knees and running board brackets are laid off, the holes drilled and tapped, and studs put in to suit. The holes for the handrail columns, fittings for the injectors, pumps, blower valves, blow off cocks, etc., are now tapped or reamed as the case may be and these fittings screwed into, or bolted fast to the boiler. The throttle, dry pipe, and steam pipes are put in and bolted up. The dome cap is bolted up against its gasket. The sand box, bell, etc., are attached to the boiler G, to their corresponding studs and the boiler thoroughly gone over, to see that all plugs, taps, etc., have been entered.

After everything is found to be satisfactory, water is allowed to enter the boiler. When it begin to fill up, we find numerous little streams trickling from the seams and the rivets, all of which must be stopped with calking tool. After the seams have been gone over and all the leaks have been stopped, the pumps are started. As there is sure to be some air in the boiler, and some leaks, the water pressure will go up slowly at first. As the leaks are stopped, the pressure gradually creeps up until it reaches the point specified for the hydraulic test, which is about 40 to 60 pounds above the working pressure. This pressure

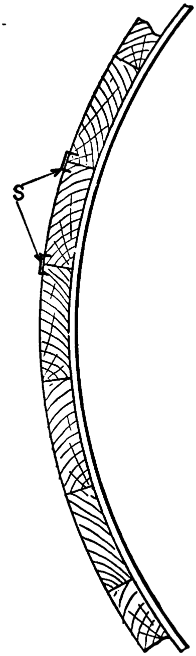


Figure 288

Section showing lagging.

is maintained until all the leaks are stopped. The pressure is taken off and a plug in the waist or in the water space is removed and the water allowed to run out.

After this the boiler is connected up to a steam pipe. The pressure creeps up quite slowly owing to condensation, and the temperature of the boiler follows until the full pressure specified for the steam test is reached. This is from 20 to 50 pounds above the working pressure. If leaks should show up again they must be calked. The throttle can be opened and the steam allowed to enter the cylinders. Any steam test can be made, or such tests can be made later on. Ordinarily these boilers are never fired in any of these tests.

The boiler is now ready to be lagged. The style of lagging depends upon the service that is required of the boiler, the expense, etc. Magnesia sectional lagging, however, is mostly used, but whatever the lagging may be, it is usually put on in sections. The different sections are held together by staples S, Fig. 288, and also by wires which encircle the boiler and hold the lagging firmly to it. This lagging is sawed off to suit and chopped out with a hatchet to fit the different places. The graduating for the sheets, Fig. 289, is done by the makers of the lagging, who are furnished with a print of the boiler with the lagging shown. They then get out the required number of pieces and make up the different courses so that it is not such a big job to find just where the various pieces go.

The lagging stops at the front tube sheet and is never put over the smoke box. It is usually allowed to run over

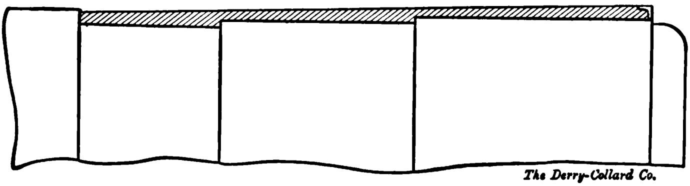


Figure 289

Showing lagging graduated.

the outside crown sheet and back as far as L, Fig. 290. The angle iron here shown usually extends down to the cab board and the lagging is fitted under it as indicated.

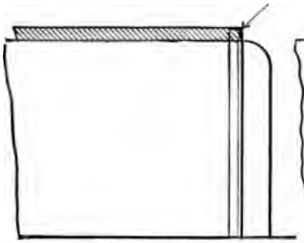


Figure 290

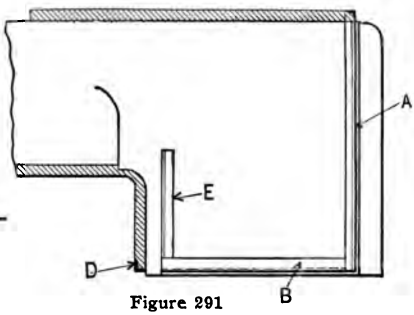


Figure 291

The Derry-Collard Co.

Showing where lagging stops.

Sometimes, however, the whole lower portion of the fire box is lagged. Then the angle iron extends down the back as also shown at A in Fig. 291, extends along the bottom as indicated at B, then a piece along the throat sheet at E and also along the front of the fire box at D. Holes are drilled into these angle irons and wire is threaded through these holes, back and forth to hold the sections in place.

On small locomotives, wood is frequently used for lagging. The pieces are laid together with a small air space between them and bound to the boiler with strap

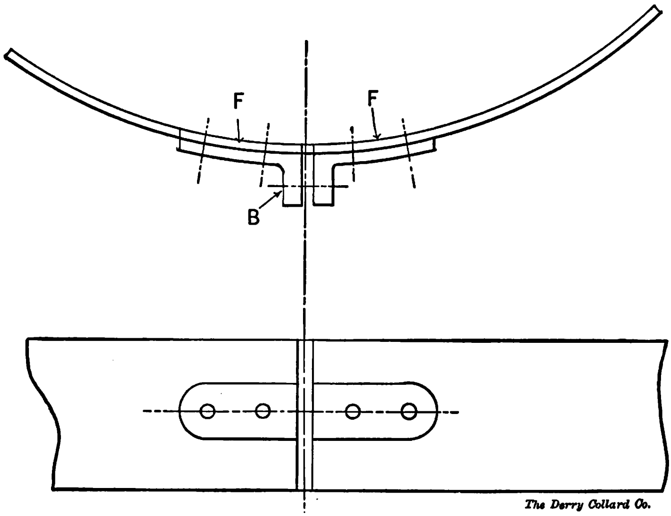


Figure 292

Showing how jacket bands are fastened.

iron. Short nails are driven through the hoop iron and are turned over against the sheet of the boiler. This makes a cheap lagging and one which is easily put on, although not as good as the sectional lagging.

All the feet on the sand box, the bell and anything else that might be bolted on to the boiler must be short enough to be covered by the lagging. All plugs, injector connections, hand rail columns, etc., which go through the lagging should be especially designed to suit the particular thickness of lagging which is to be used on the boiler.

After the lagging has been put into place both on the boiler and on the dome body the jacket can be fitted on. The jacket bands are made of various widths to suit the

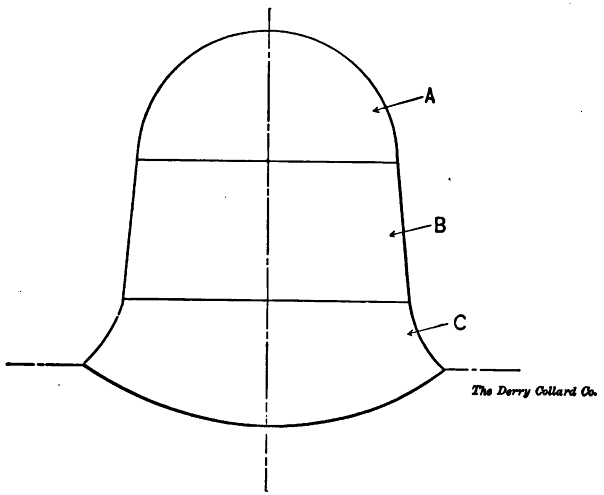


Figure 293

Dome casing.

size of the sheet and the conditions of the boiler. They are made to encircle the boiler in one piece and are held into place by clamps as shown in Fig. 292. F and F are knees that are riveted fast to the ends of the band and are drawn up by a bolt B. These clamps are always arranged so as to be underneath the boiler or at a place which is not readily seen.

The dome is covered by a casing, Fig. 293, which is made in three sections, A being spherical, B a conical shaped sheet, and C is flanged out so as to join up neatly with the jacket. The rivets are countersunk in the flange so as to clear this casing. In a similar way the sand box is also covered up and if there are any other projecting parts of the boiler inside of the cab, some form of covering is provided for them. The back head is also covered and must be cut out and pieced to fit around the various fittings.

Boiler Shop Machinery.

On account of the enormous delay in getting out work sometimes due to the machinery being out of order, it has been deemed advisable to devote some space to the description, care and repairs of the machines of the boiler shop. One of the first operations upon any sheet of metal, is shearing. Fig. 294 represents a shear with a large capacity and a deep throat. The shear blades B should be kept in good condition, there should be very little clearance between the blade and the cutting edge which should be ground to an angle of 8 or 10 degrees. The capacity of the machines should never be exceeded. If a machine is only intended to shear three-quarter plate, one should never try to shear inch plate. If this is done, and by speeding it up it can be done, some day you will find that you have a broken frame on your hands. This is sure to happen when there is a big rush of work on hand.

Another source of trouble lies in the clutch or gag.

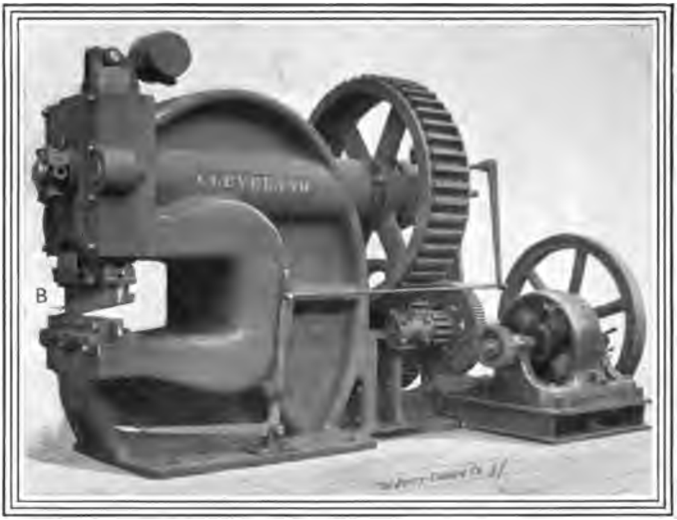


Figure 294
Shear used in boiler making.

The pressure necessary to shear a plate is so great that all the surface of the clutch or gag is necessary to do the work. If only a small portion, therefore, is allowed to catch, the corners will either wear or break off—a condition of affairs which is only too frequently seen in nearly every boiler shop. The clutch or gag should be made to take a sure hold, either by a spring or a weight. If the machine is motor driven, the electrician should see that the motor is always in good running condition.

The constant tendency in the boiler shop is to set

An hydraulic shear.

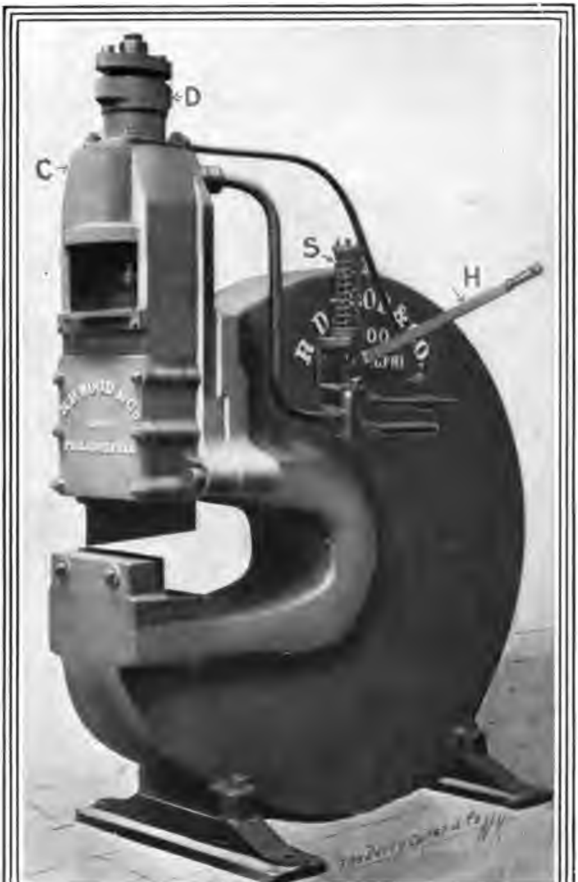


Figure 295
An hydraulic shear.

aside mechanical shears for hydraulic ones. A good example of such a shear in seen in Fig. 295. When the handle H is drawn down, the accumulator pressure is admitted into the main cylinder C. This pressure forces the ram and also the blade downward and shears off the

Figure 296

A shear for round and square bars.

plate. A draw back cylinder D always has the accumulator pressure acting upon it. As the spring S returns, the handle closes the valve and also opens the cylinder C to exhaust, the accumulator pressure returning the ram.

A splitting shear.

There are thousands of round and square bars to be cut off from long rods in connection with boiler work, and some style of hydraulic or mechanical shear is used for this purpose. Fig. 296 illustrates a hydraulic shear for this work. The normal position of the shear is up, as shown. When the handle H is pushed down, water is admitted through the pilot valve P and thence flows through the small pipe T to the main value S. This pressure forces the valve along and opens a passage to the main cylinder. The plunger lowers and a small trip engaging with the lever returns the handle H. The accumulator pressure then forces the valve S open and the water in the main cylinder is allowed to exhaust. The constant accumulator pressure in the draw back D returns the cylinder. The principal thing to be watched in operating these machines is to keep the packing drawn up tight and renew it when it begins to drag out. The leather packings are easily renewed at the end of a day and should never be allowed to run after they have once started to leak.

There are many narrow strips about a boiler which are necessary for the different parts and are cut with a splitting shear shown in Fig. 297. One side of the shear along A is kept a little inside the cutting shear, so the straight sheet can pass along this line. When the machine is used for extra heavy work, a bar is placed through the lugs L and L to strengthen the frame. The machine runs constantly and the blade is made to operate by means of the handle H. This throws in a gag and when the eccentric lever comes down, it pushes the shear blade with it. On account of the load on the shear blade coming out of center, the guide wears away very rapidly. A taper shoe S is therefore used to take up the wear and as soon as the

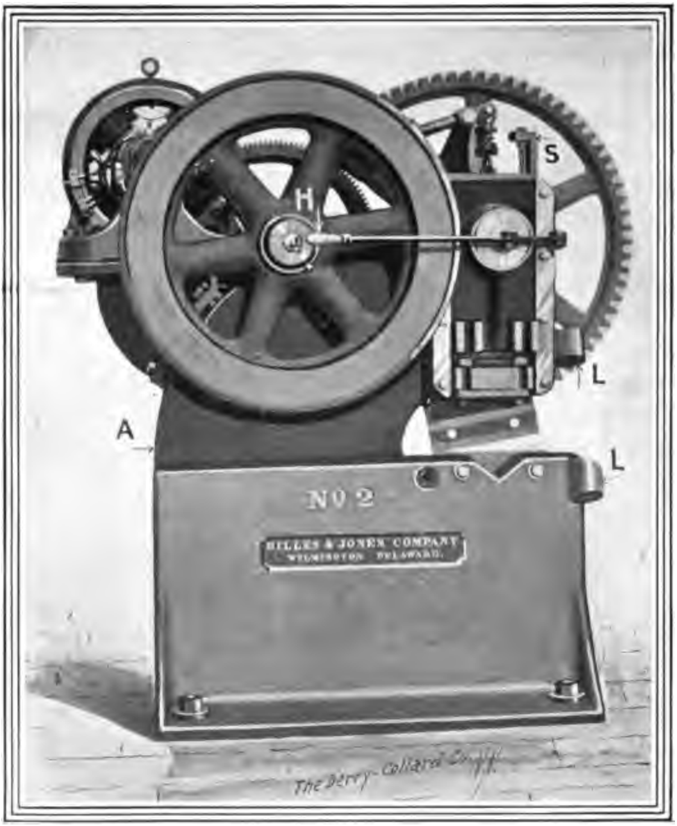


Figure 297

A splitting shear.

head becomes loose, it can readily be seen and should be taken up by this shoe.

As there are a large number of boilers built on the style of the one in Plate 2, there is a constant need for beveled edges around irregular curves. We therefore find in some boiler shops, a narrow angle shear, Fig. 298, or else a machine that is made very similar in general appearance but has rotary shears.

So much angle iron is used in staying and otherwise

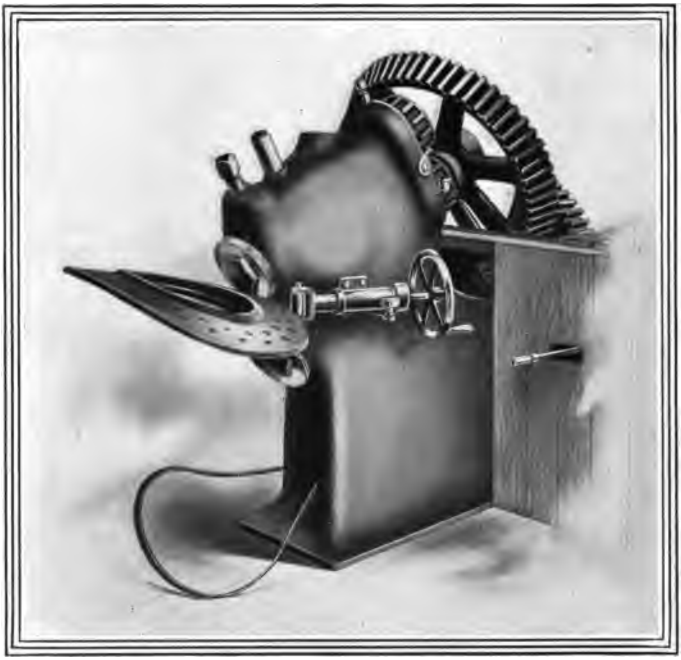


Figure 298
A rotary or bevel shear.

about a boiler that large quantities of this angle iron must be cut to certain lengths. The angle iron shear, Fig. 299, represents the style of machine that is used for this purpose. The shears are double. Angle iron of small sections can be sheared off by sticking one end of the bar into the machine and holding the other by hand, but large sections must be held to the table T. Slots S are provided for the clamping bolts. When shearing off angle iron at

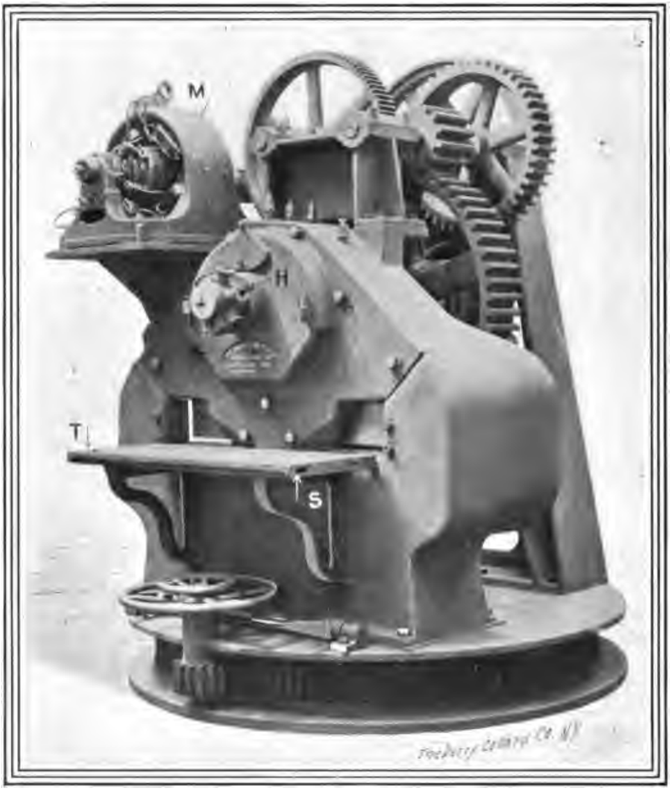


Figure 299
An angle iron shear.

an angle it is necessary to brings the blade down against the work before the foot lever is thrown into operation.

For this reason a bar is put into the hole H and by turning it, any required position can be obtained. The tendency is to drive these large machines by individual motors as at M.

A large hydraulic flanging press is shown in Fig.

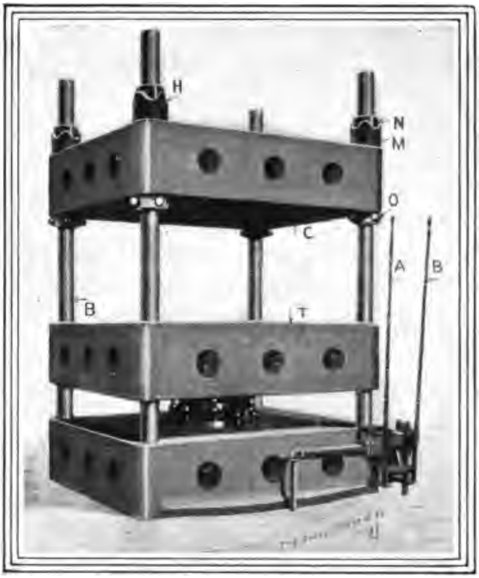


Figure 300

An hydraulic flanging press.

300. The dies are bolted in T slots upon the table T and also upon the cap C by means of columns which have already been explained under flanging. B are the four tension bolts along which the table slides. The cap can be adjusted by the nuts M and O. The nut N should always

be placed on top as the lower nut M is only intended to lock it. The half nuts O serve to support the cap on the bolts. When it is desired to raise or lower the cap, four columns of equal length are set upon the table, one near each post. The nuts N and M, having been adjusted, the main table is brought up and the four columns raise the cap perfectly level to the required distance. While holding the machine in this position, the nuts O are screwed up against the cap. The table is then lowered and the nuts N and M are drawn up tight. These nuts are adjusted by sticking a short bar of iron in the holes H and then knocking the nut around with the hammer; this is much more readily done than by using a long wrench. A is the handle which operates the main valve and B operates the internal plunger. When the handle is thrown in one direction, water is turned in and when it is thrown in the opposite direction the water is exhausted.

In Fig. 301 we have a machine which, in addition to having a main and an internal piston, has four auxiliary pistons A and a top cylinder T. The auxiliary cylinder must be adjusted radially, in order to accommodate the shape and size of the dies. The top cylinder T is arranged so it can be adjusted in and out from the center. It is very useful for light flanging. The power required for operating the press is much misunderstood. Every time any one of the pistons is operated without doing any work as much steam is consumed in running the pumps to supply this water, as it would take if these pistons were working at their full capacity. On this account much expense is saved in the operation of the hydraulic plant by careful manipulation of the valves.

Fig. 302 represents a universal flanging press. A and B are vertical pistons which can be operated independently of each other. They are returned by the draw back D. C is another piston which operates at right angles to A and B. L is an angle plate, along which the piston B slides. Many of the boiler plates which are bent

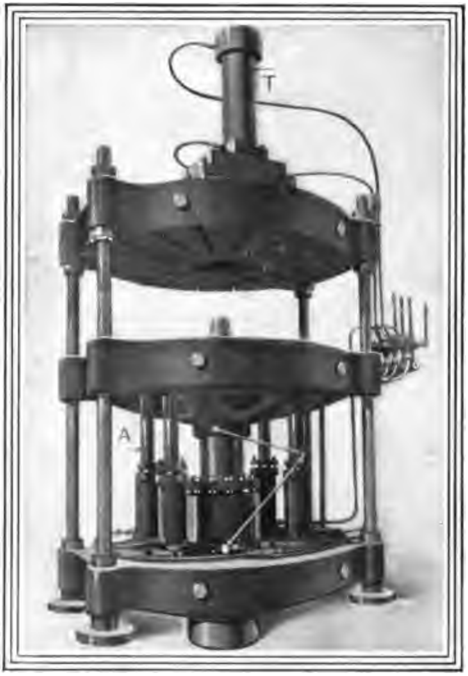


Figure 301
An hydraulic flanging press.

in the form of channels and which are used for staying the heads can be made under this machine.

For bending a plain sheet at right angles, a die is places underneath the piston A and the sheet is pinched and held in position by A. Next B is lowered and the sheet is flanged. B is then returned and C brings the flanged portion tight against the die, thus finishing the

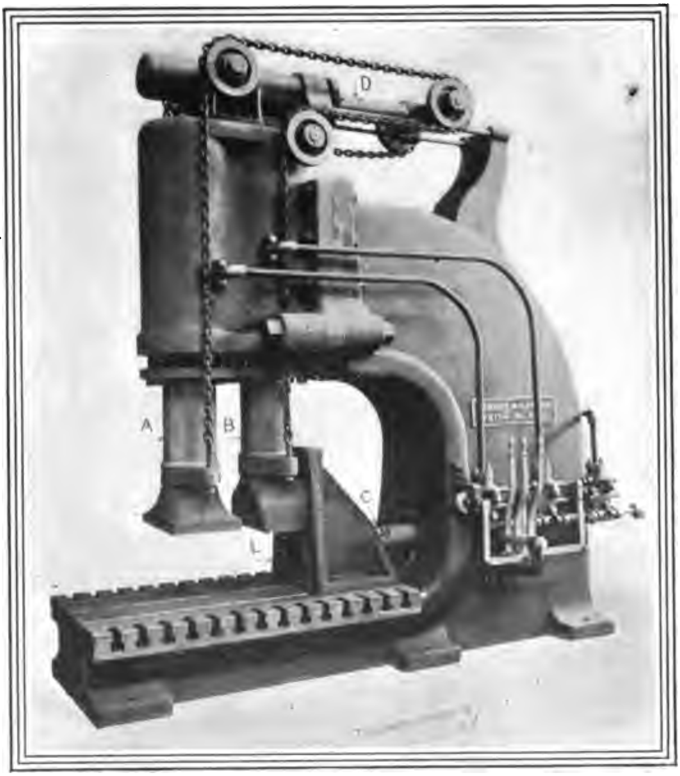


Figure 302
A universal flanging press.

operation. Much of the hand work usually done on account of not having complete dies, can be done on this universal machine. The sheet is held the same as the one just mentioned and one section after another is flanged by the pistons B and C.

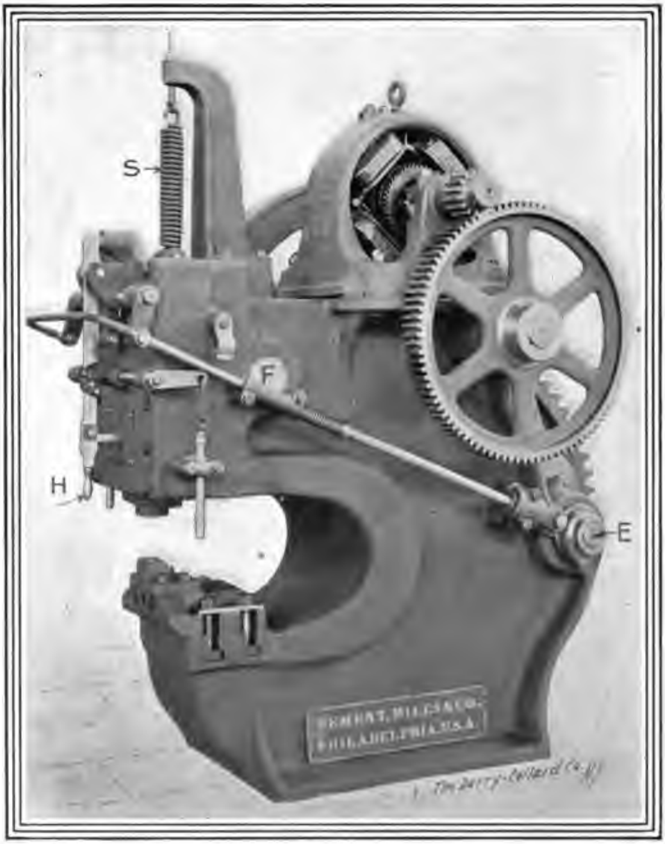


Figure 808

An electrically operated punching machine.

A punching machine will be seen in Fig. 303. Instead of a counter weight, a spring S is used to counter-balance the head. This spring should be adjusted so that the head is always over counterbalanced, so that when the punch hits the sheet, no lost motion will have to be taken

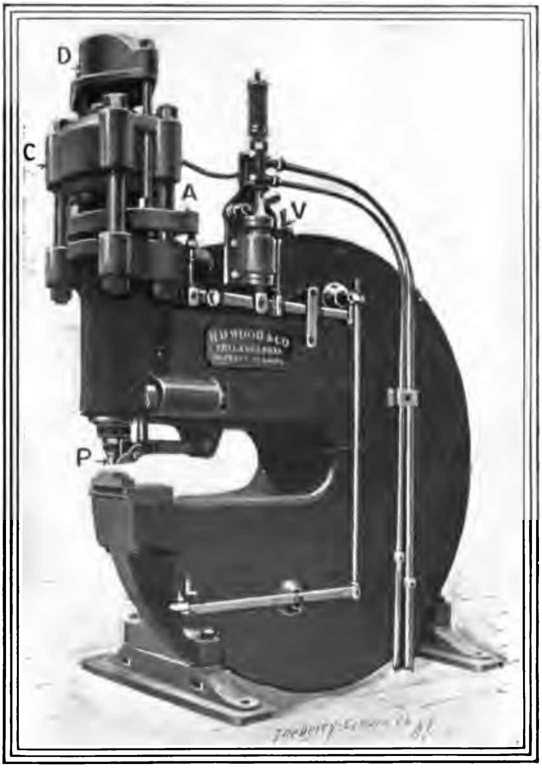
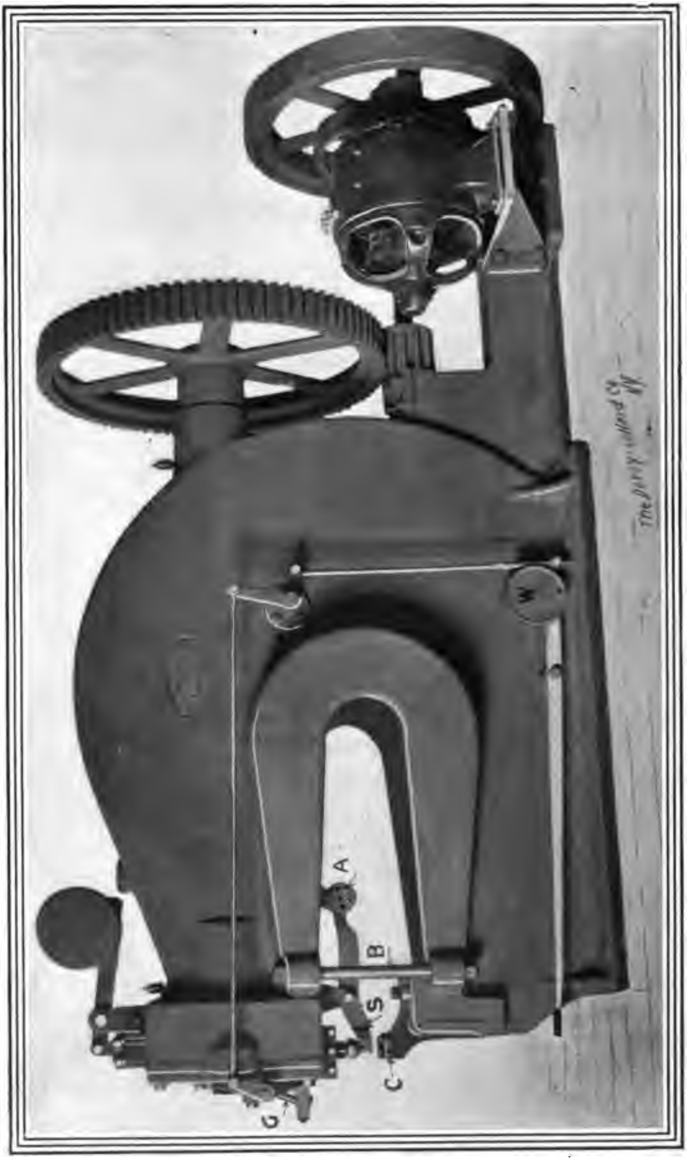


Figure 304

An hydraulic punch.

up. H is the handle by which the punch is operated. The punches are usually run at a speed ranging from 15 to 25

A punch for wide sheets.



strokes per minute. Where the punch is used for cutting, the speed can easily run up to 25 or 30 strokes per minute. But where single holes have to be punched and the centers of the holes must be felt for, 20 strokes per minute is about right. The head of this punch is forced up and down by means of a lever which has its fulcrum on the shaft F and which is thrown up and down by an eccentric on the shaft E.

Fig. 304 represents a hydraulic punch. This punch is arranged to be operated by a foot lever L which in turn opens and closes the valve V as the water rushes into the main cylinder C, the punch P is forced through the sheet. At the same time a lug A strikes a stud underneath and throws the valve over to the exhaust side, the water in the draw-back cylinder D pulls the punch out of the sheet and exhausts the water from the main cylinder.

The constant tendency in boiler construction is toward larger sheets and frequently much larger sheets would be employed if they could be obtained from the mills, but ten feet is the limit in width for shipment by most roads. These wide sheets require punches with large gaps, as Fig. 305.

The enormous weight of a machine with this size gap is due to the metal necessary to withstand the severe bending action with so long a lever arm. Most machines of this size gap, therefore, only go up to a certain size hole in the plate. When larger capacity is required, a pair of bolts B are used for supporting the extra load. This of course cuts down the gap. However well a punch may be kept, the plate will stick to the punch on the return stroke, and some arrangement for stripping off this plate must be provided for. This stripper must also be provided with an adjustment for a different thickness of plates. Five adjustments are gotten by means of the lug A on stripper S.

It will be noticed on this machine that instead of having a spring to keep the gag out of place, a weight W is used for this purpose so there can be no breaking of springs nor any changing of tension.

The stake C on this machine is made of forged steel

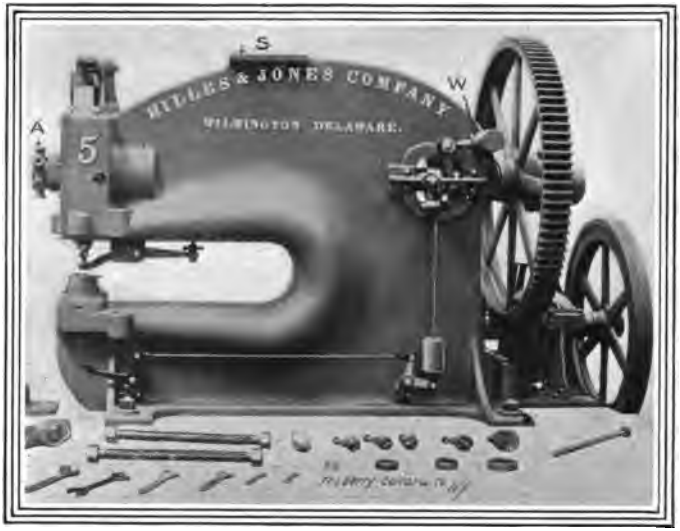


Figure 806

Punching tube sheet holes.

and is very narrow, extending out beyond the nose of the machine. This enables one to get in close to the corners of flanges, and also to punch holes readily into flanged heads, which is a very convenient thing on a vertical punch.

When punching tube sheet holes, the tit of the punch should be entered with unfailing certainty into the center punch mark. There should be no chance for its getting out before the hole is punched. The wheel A, Fig. 306, enables one to raise and lower the head until this condition is attained. The foot treadle is then depressed, the

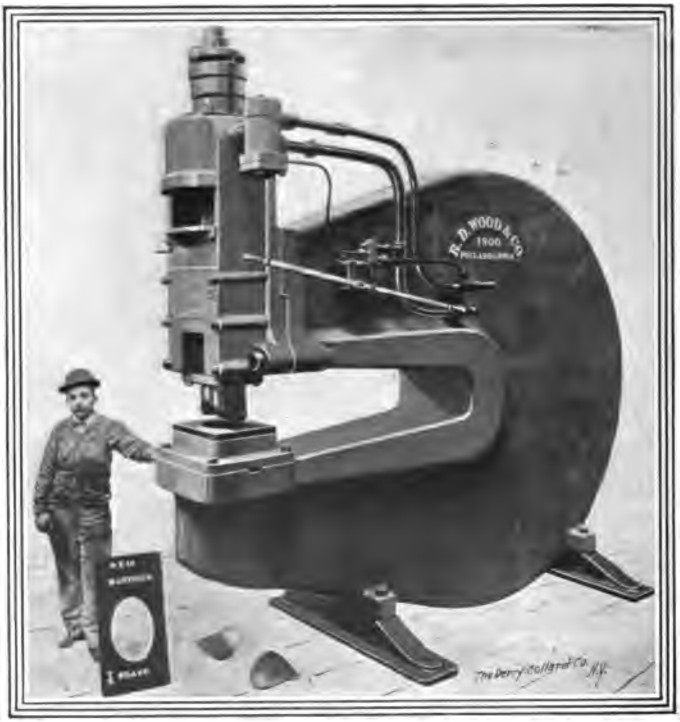


Figure 807

Punching large holes.

bell crank with its weight W is released and the clutch is engaged. As the eccentric shaft then rotates, the punch is pushed through the sheet. Weights instead of springs are noticeable in this figure. A shelf S is provided for a crane. Nine machines out of ten have jib cranes rigged up on them.

When a large number of the same size locomotive boilers are built, there are hundreds of sheets to be cut out for the fire door, for dome flanges, etc. Some boiler shops

Figure 308

An automatic punch and shear.

have machines especially fitted up for this class of work. Fig. 307 shows one of these machines operated by hydraulic pressure. The shape of the punch is such that the sheet is sheared as is clearly shown in the engraving.

To save time in laying out sheets an automatic punch and shear, Fig. 308, is used. This represents one

A horizontal punch.

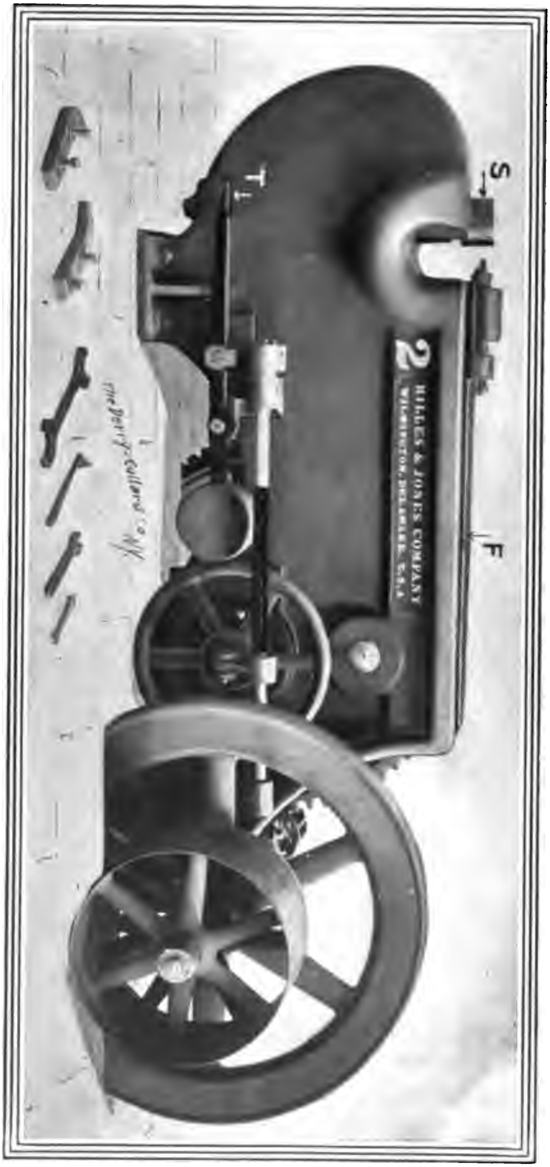


Figure 309
A horizontal punch.

of a class of machines which will shear one edge at an angle, space the sheet and punch the holes accurately along the full length of the sheet, the sheet being clamped upon the table T. Some of these machines not only space the rivets in even figures but into any decimal part of an even space. That is if we have a sheet say 200 inches long and wish to space 77 rivets in the whole length of it, this machine would space the rivets accurately to $^1/_{77}$ of this distance. The shears on these machines are set at an

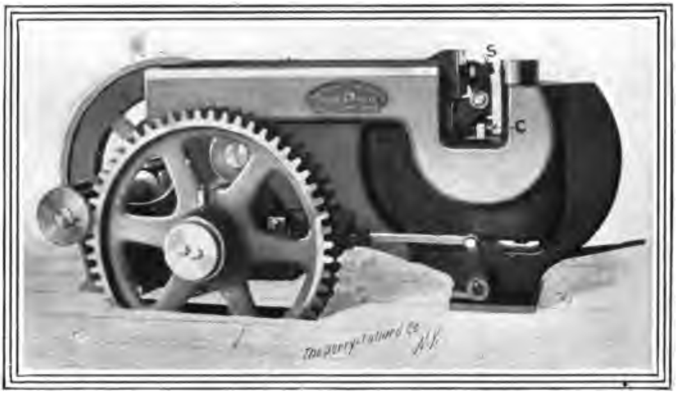


Figure 310
Horizontal punch with stripper.

angle so that no planing is necessary when the plate comes from the machine.

However well a vertical machine may be arranged for punching flanges, there is scarcely a boiler shop that does not have one of more horizontal punches. Fig. 309 represents a horizontal punch with a circular steel stake S. The gap is seen to be very small and the top of the machine is flush at F. This is necessary when punching off the extra metal around a fire door flange. The foot treadle is shown at T. When these machines are used for punching holes, a stripper is as essential as on the vertical machines, so we find a rig like S, Fig. 310, arranged for stripping off the plate. This is adjusted by the screw C for plates of varying thicknesses.

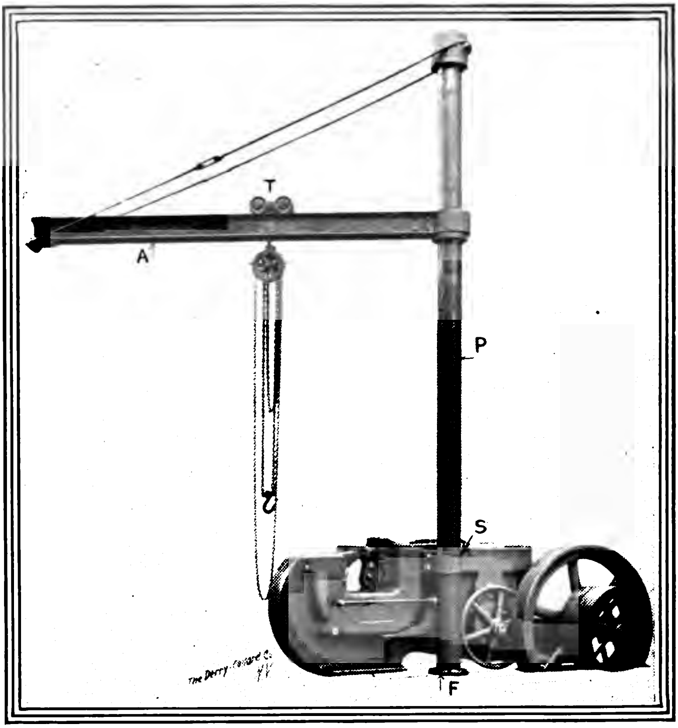


Figure 311

Punch with attached crane.

The dies are held in the stake by headless pointed set screws. The clearance holes for the punches should be large enough so that they will not clog up. All these

A plate planing machine.

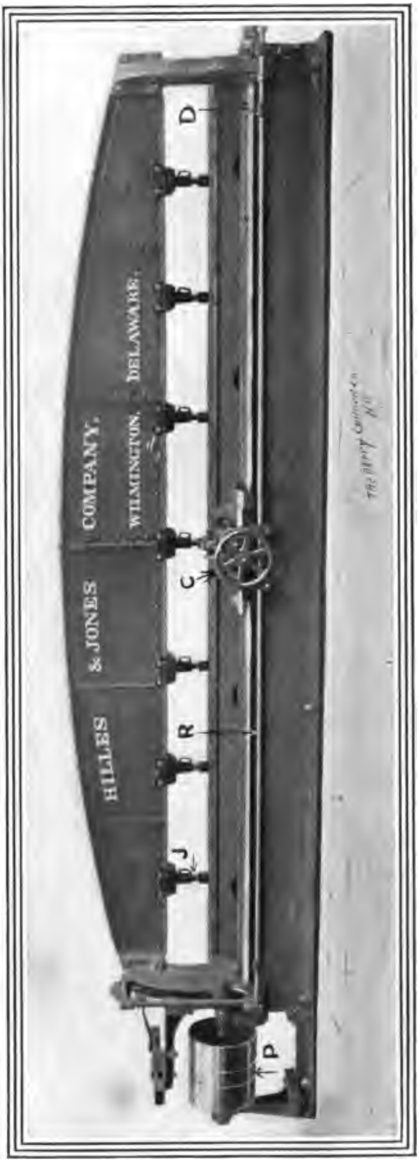


Figure 312
A plate planing machine.

Plates held by jacks.

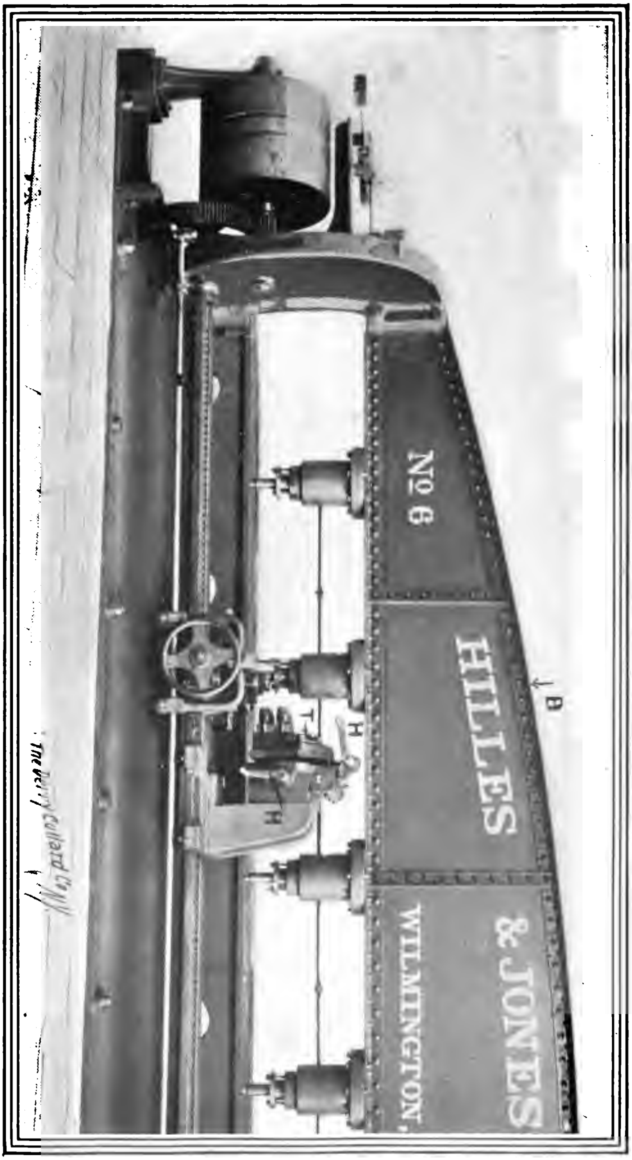


Figure 313
Plates held by compressed air jacks.

Dog arrangement for reversing.

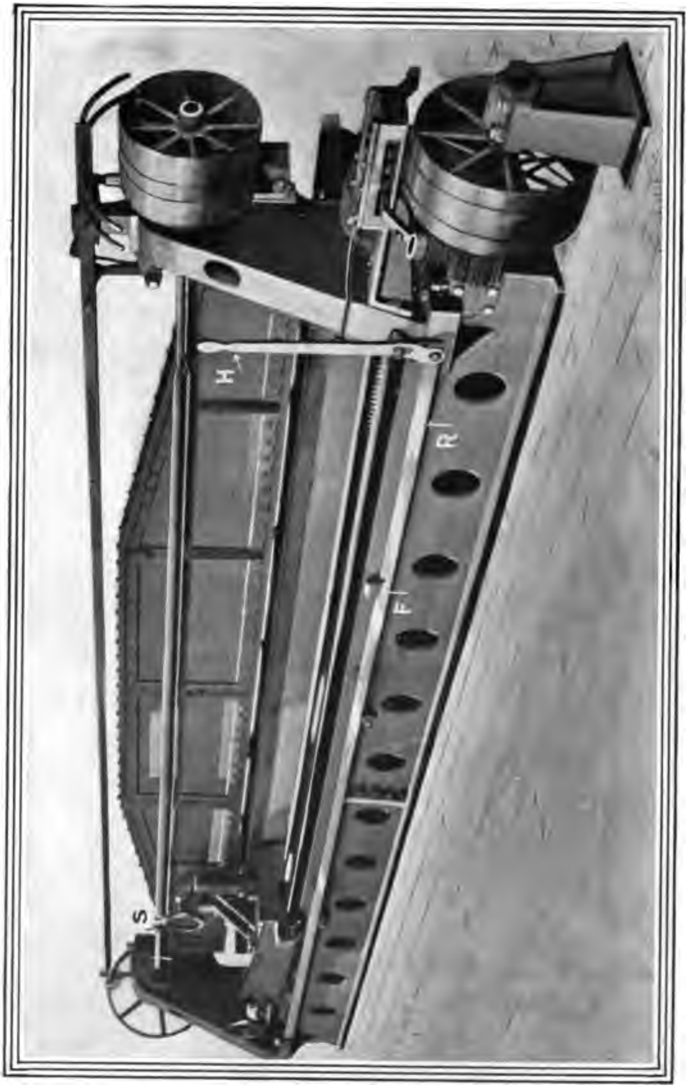


Figure 314
Dog arrangement for reversing.

machines should be fitted up with individual cranes. The style represented in Fig. 311 is a convenient arrangement. The post is fastened to the floor by a flange F and to the machine by a strap S. The arm A swings in a circle and by means of the trolley T the sheet can be swung in any position required.

A plate planing machine with a long steel beam for clamping the sheet is illustrated in Fig. 312. The tight and loose pulleys P rotate a screw, which engages a nut and draws the carriage C along. Upon the rod R, dogs D are placed and these limit the traverse of the carriage and do the reversing. The jack screws J can be distributed as shown or can be bunched in any part of the machine so as to hold a very narrow sheet.

Fig. 313 illustrates a compressed air jack which is fitted permanently to the beam B. A better view is here obtained of the carriage. The tool slide swivels at any angle and is adjusted up and down by the handles H. The tool block T is hinged so that when the tool is returning, the sheet will not drag off the edge.

A different arrangement of the dogs for reversing the carriage is seen at F, Fig. 314. They slide along the rectangular rod R, which in turn is attached to the lever H. With this lever one is able to run the carriage back and forth from one position. The clamping of the sheet is done by power through the shaft S.

In Fig. 315 a large bending roll is shown, driven by electric motors. Motor A is used for driving the rolls and the other, B, raises and lowers the top roll T. The cap C is so hinged that it can be dropped out of place, while the hand wheel H through the screw, supports the rod.

In Fig. 316 T clearly shows a slot which has been

A large bending roll.

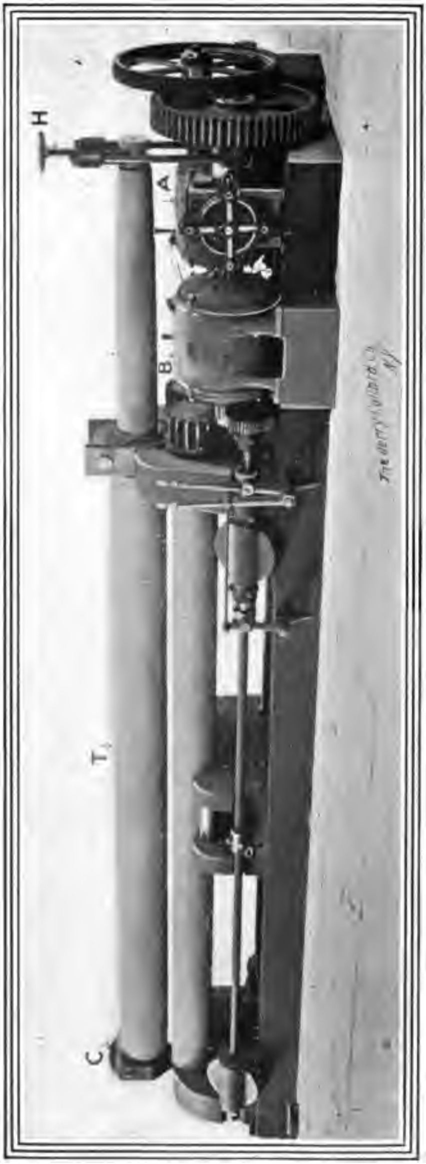


Figure 315
A large bending roll.

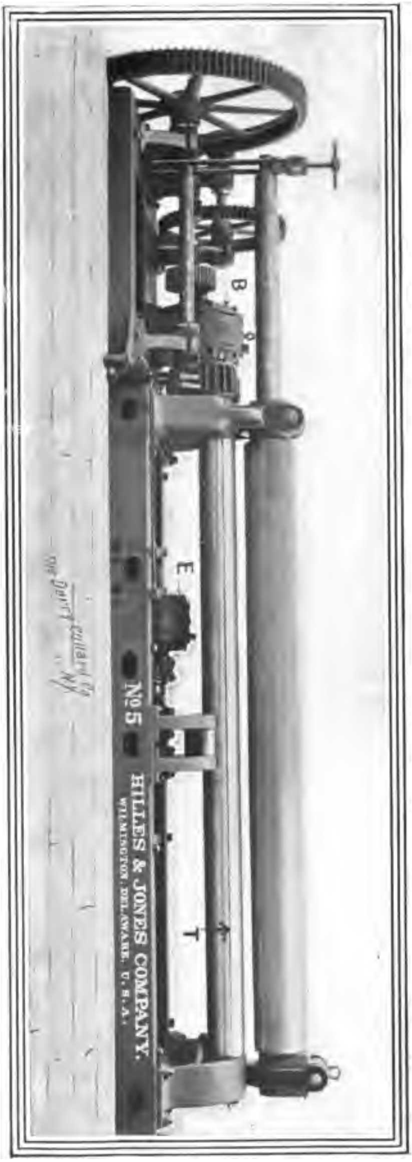


Figure 316
Bending rolls driven by motor.

referred to in the previous chapter. It is used for lining up the sheet during the process of bending. The electric motor is placed inside the bed as shown, while the bending motor B is near the head of the machine. One source of delay on these machines is in the renewal of brass pin-

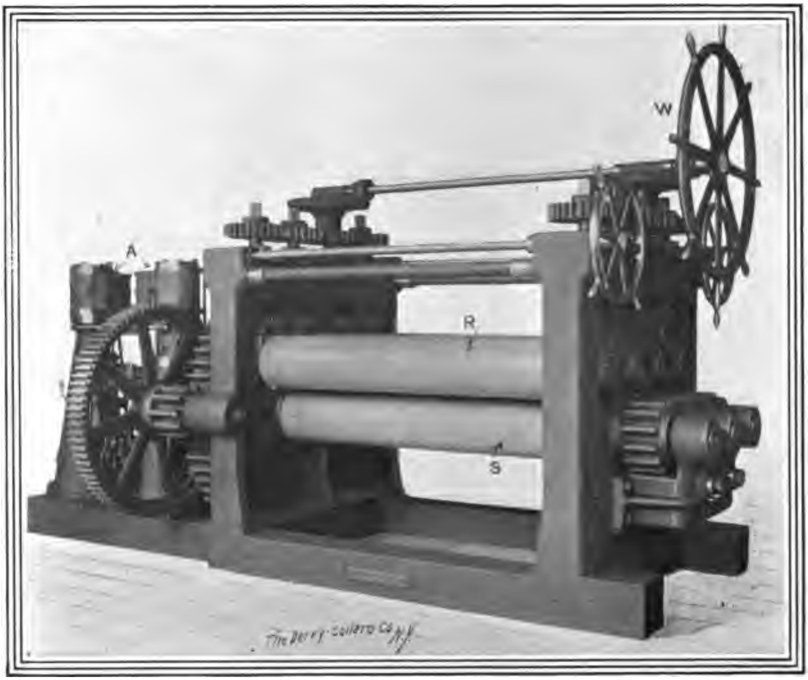


Figure 317
Plate straightening roll.

ions, as many of the gear teeth are cast and they grind and wear away rapidly. It tells more on the pinions than anywhere else and the pinions should be made of cast steel.

Fig. 317 shows a plate straightening roll. There are four upper rolls R and three lower rolls S, spaced midway between them. The upper have an air adjustment vertically to suit the thickness of the plate. They are

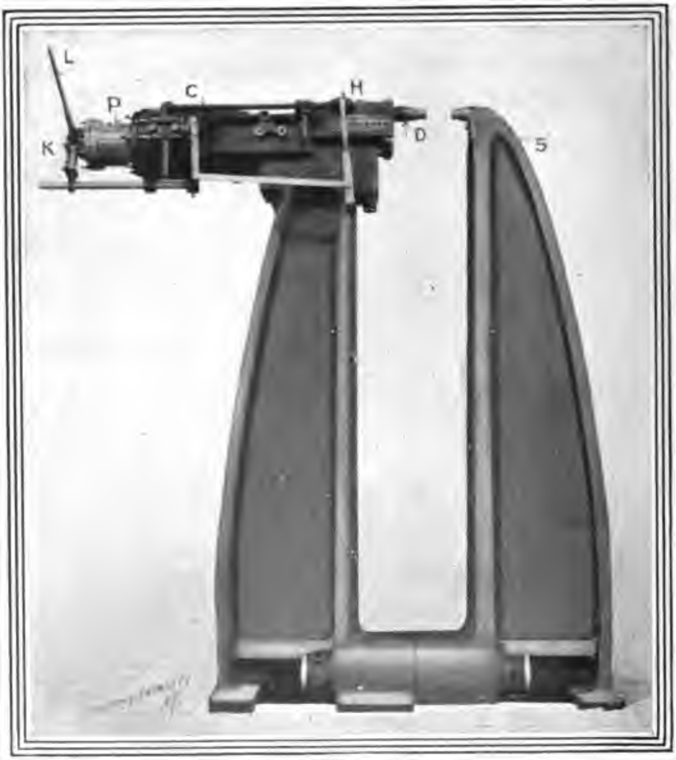


Figure 318
A flush top riveter.

adjusted by the hand wheel W and are driven by a pair of reversing engines A.

Figure 319

"Vauclain" type of riveter.

Riveting by machinery.

Under the subject of riveting, different styles cylinders have been mentioned. Fig. 318 represents a flush top machine. The valve is coupled up to the supply and to the machine in such a manner that when the handle H is pushed toward the stake S, water is turned into the cylinder and the die D approaches the rivet. This represents a three pressure machine, the various pressures being obtained in this manner. There is a main cylinder C, an intermediate piston P and a small piston K. P and K can be locked to the main cylinder by means of a screw inside the cylinder. This screw is revolved by the lever L. The screw is cut away in three places like the breech of a gun and thus by a small motion of the lever L the screws engage or disengage as the case may be.

Some precaution must be taken in coupling up the different pressures. If the screw threads are not fully engaged, the enormous pressure of the piston will either break the screw or strip the thread in the nut. In order to get the lowest pressure, the lever L must be unlocked, the piston P and K pushed in and then the lever L locked.

Fig. 319 illustrates another style of cylinder. This is known as the flush bottom or "Vauclain" type. The different pressures are obtained through a distributing valve from which pressure is entered into several different chambers which will give either one of the three pressures. H is the valve handle for operating the riveter. The valve for operating the crane when the crane is hydraulic is placed nearby, so that the operator has both under perfect control. On account of the eccentricity of the load, the bolts B stretch and gradually work loose. They should be looked after occasionally.

Portable hydraulic riveter.

Figure 320
Portable hydraulic riveter.

Portable hydraulic riveter.

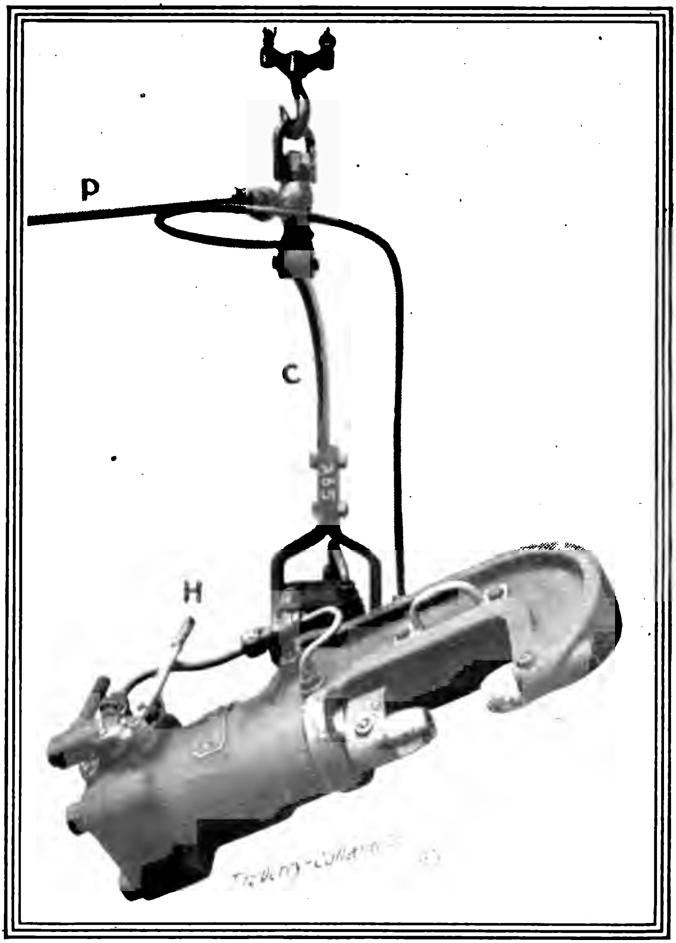


Figure 321
Portable hydraulic riveter.

A pneumatic riveter.

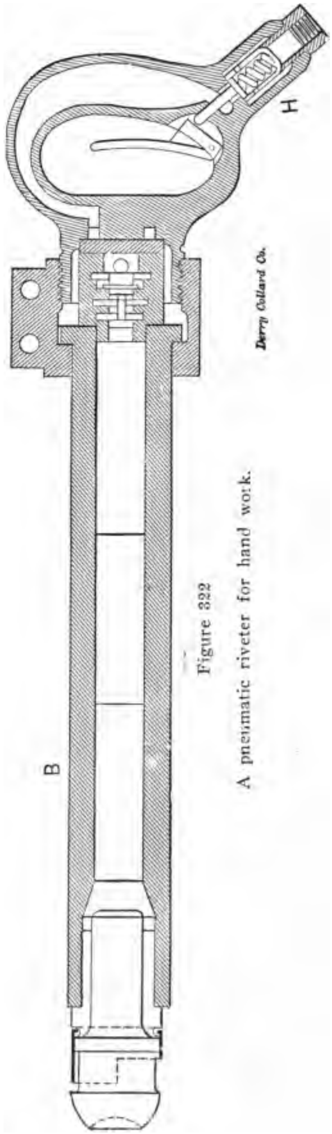


Figure 322

A pneumatic riveter for hand work.

The bolts D should always be drawn up so tight that the joint line L will never open when the machine is in operation. These bolts can be heated up for a distance of two feet or so, with a charcoal fire, and expanded. The nuts N should then be hammered to take up the slack and when the bolt cools it will be under tension.

In Fig. 320 is a portable hydraulic machine. The gap, of course, is small, but there are many rivets in the boiler which can be put in with one of these machines

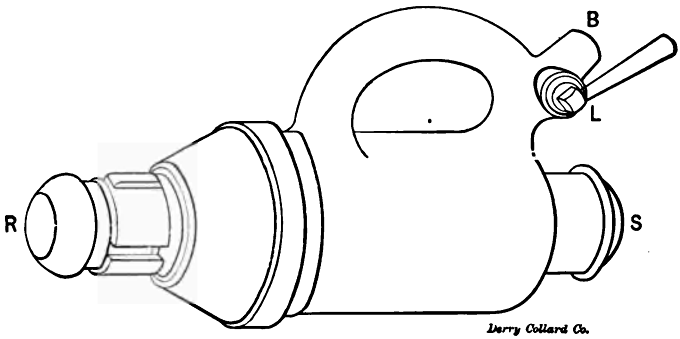


Figure 323
A pneumatic "holder on."

when it is on the floor, which would otherwise have to be hand riveted. P is the supply pipe. H is the operating valve handle.

For driving the rivets in the water space frame, the portable hydraulic machine, Fig. 321, is useful. C is a circular arm which supports the riveting machine and which admits of its free movement in any direction. H is the handle for operating the main piston. P is the supply pipe which is arranged with several joints. This enables the crane hook to be raised or lowered or shifted in any other position.

For driving rivets with an air riveting hammer, **Fig. 322**, the barrel B should be arranged for an extra long stroke. For boiler rivets, unlike rivets for structural steel work, must not only be headed up but the metal of the rivet must be driven tightly into the hole and the head must be driven down solid. This can only be done

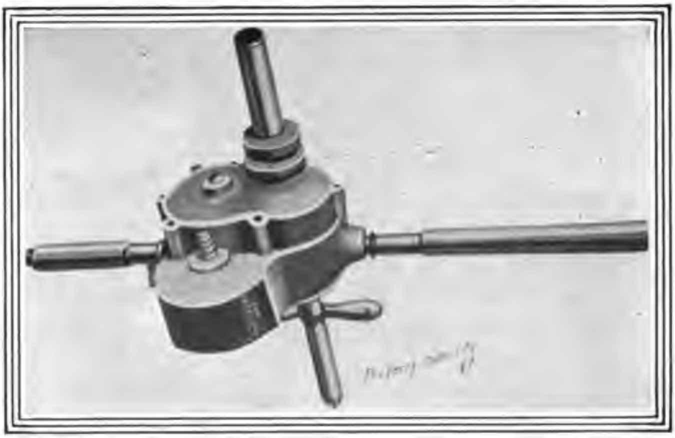


Figure 324
A pneumatic piston drill.

by heavy blows. The handle H opens and closes the valve.

The old method of holding the rivet will gradually give way to a much better and a more satisfactory method which is to be found in the holder in Fig. 323. The air hose is coupled up at B and the valve is open. The air pressure then acts as a spring between the end R for the rivet and the end S for a support. This holds the rivet in place with a pressure of 1,000 or 1,200 pounds.

Layout of riveting plant.

Considerable power is required to drive the tapered reamers used for reaming out the rivet holes. On this account the small rotary motors are no longer able to do the work. There are a number of piston drills, Fig. 324, placed upon the market which give an enormous torque. They are usually arranged in two or three sets 90 to 120 degrees apart, the air hose being connected to one of the handles.

Fig. 325 shows a general riveting plant. R is the riveting machine. The crane hook H is suspended from a trolley on the bridge B. The chain is anchored at A, then goes down around the block and returns to the bridge. From here it goes down to the bottom sheave of the hoist B. C is the accumulator, T is the supply tank and P is the pump. The pump runs the accumulator up until the weight W is lifted by it. A weight at the other end of the chain closes the steam valve and stops the pump. Water is then used from the accumulator for the hoist, for riveting and perhaps for several other machines.

On account of a number of machines being operated from the same accumulator, much annoyance has sometimes been caused by shocks from the water pressure when the valve leading to the main cylinder of 150 tons riveting machine is opened. The water rushes into the cylinder at an enormous velocity. This flow reduces the pressure in the supply pipe, making it appreciably lower. This valve is now suddenly closed and as the 50 or 75 tons weight of the accumulator cannot be stopped suddenly without causing the pressure to run up enormously, we have this shock in the mains. Whenever several machines are operated from the same accumulator, a shock valve, Fig. 326, or some form of safety

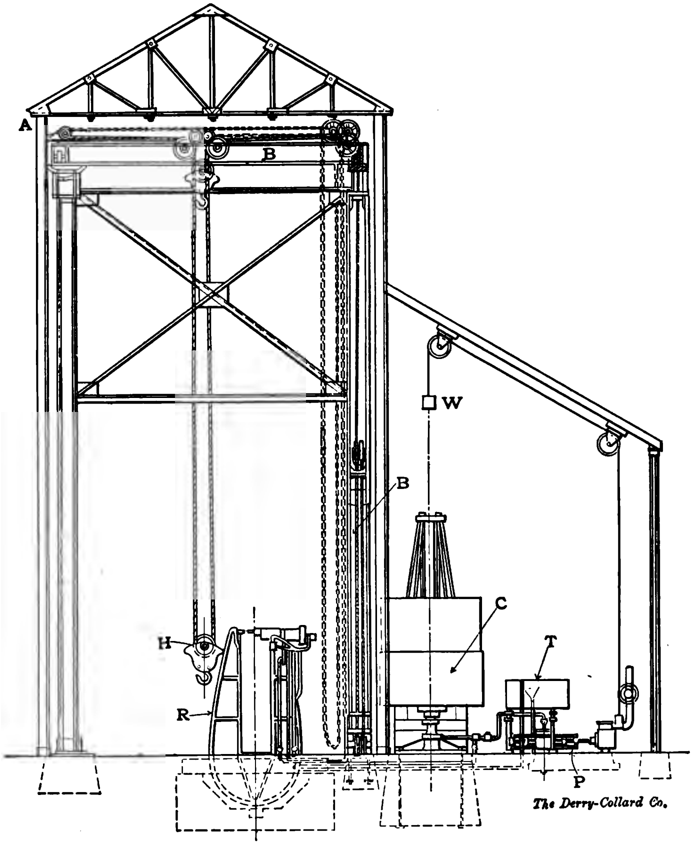


Figure 325

View of general riveting plant.

valve, should be employed. P is the piston which has the accumulator pressure acting against it. Its upward tendency is resisted by the spring S. When the pressure in the main line suddenly rises, these springs will give and consequently relieve the shock.

Oil heaters were mentioned under riveting. Fig.

Figure 326
A relief valve for hydraulic tools.

327 gives an idea as to how these heaters are arranged. They are lined inside with fire brick, one of the pipes supplies oil, another is connected to the steam or air pipe. They are placed on the platform near the operator.

The majority of the work for drilling holes in boiler plates and flanges, etc., is done under a radial drill. Such a drill is illustrated in Fig. 328. The table can be made to swivel to any angle and with a clamp can be held in any position. It is raised and lowered by

Oil heater for rivets.

Figure 327

Oil heater for rivets.

A radial drill.

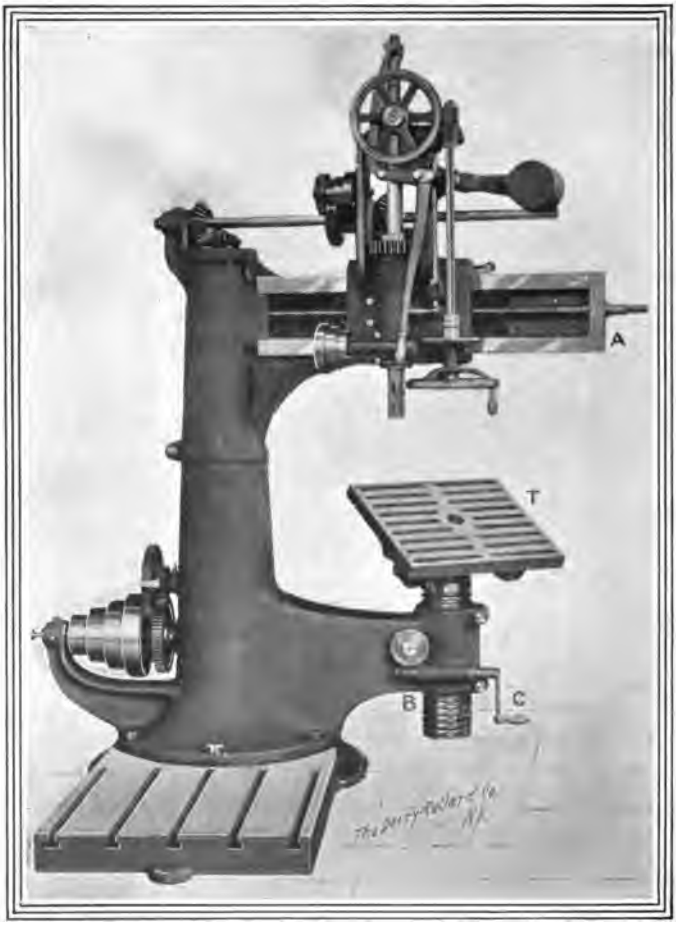


Figure 328

A radial drill.

the crank C. A circular rack on the part B allows the table to be swiveled around in any position. The arm A can be made to swivel through a complete circle. A pit is usually provided on one side of the machine, so that operations can be performed on long work.

A much more simple style of radial drill is repre-

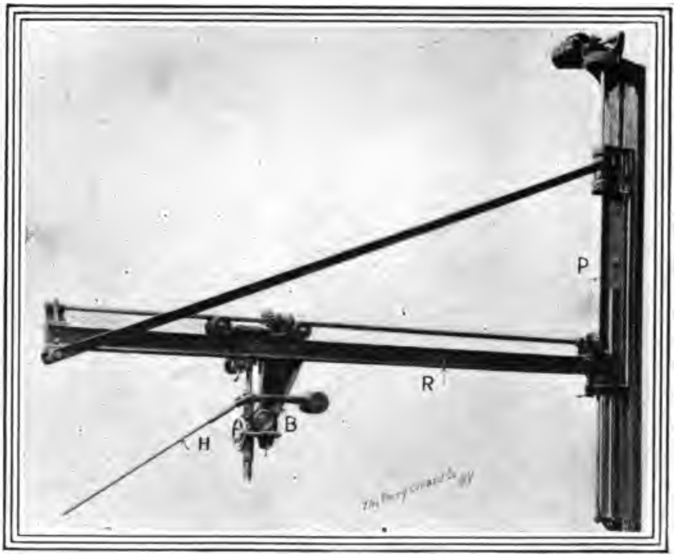


Figure 329

A radial drill hung on post.

sented by Fig. 329. This is bolted against the post at P. The body of the drill B can be shifted back and forth, and with a handle H the drill or reamer is forced into the work. Hundreds of these drills can be found in the boiler shops throughout the country. Although it is not an accurate drill, it is quickly and easily applied and for

A multiple spindle drill.

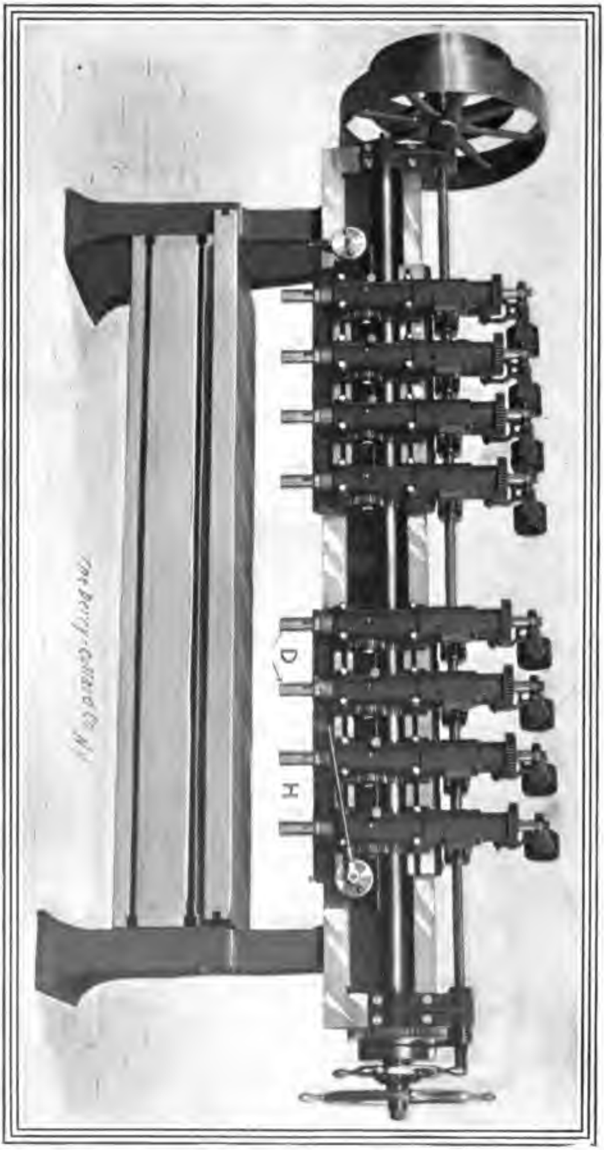


Figure 330
A multiple spindle drill.

this class of work extreme accuracy is not so important.

For the rivet holes in the water space frame, drills similar to Fig. 330 are almost universally employed. The drills D can be shifted to any position within the limit of the machine. They are set four or five spaces apart and all

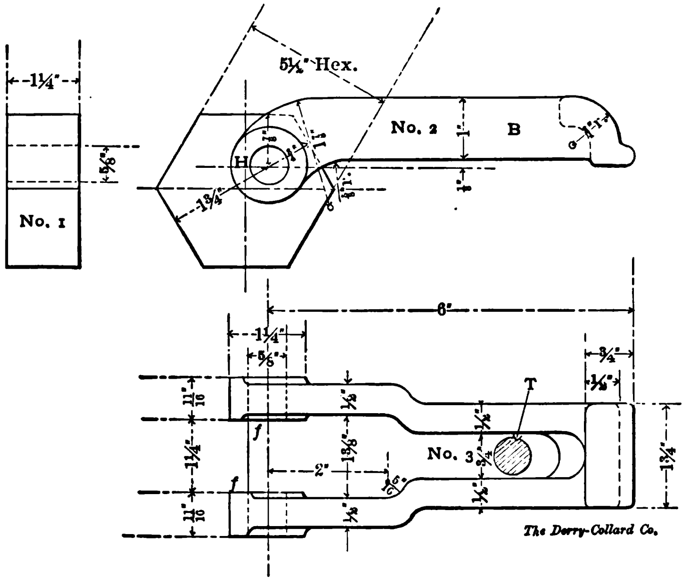


Figure 331
Clamp for holding work on drill presses.

started in to work at the same time. After the eight holes have been drilled they are shifted along to the next eight and so on. As the holes in the water space frame are equal spaces, these spindles are set to the proper space, then they are shifted to the next set of holes by the ratchet handle H which engages with a rack pinion as indicated, all the drills receive the same feed.

Fig. 331 illustrates a clamp for holding work on the bed of the milling machine, planer, drill presses, or any other place where work is to be held in place by a clamp. The hexagonal part H has a hole drilled out of center so that the distance from the center to the side of the hexagon constantly changes from one side to the other. By this means the clamp can be raised or lowered in small steps over a range of one or two inches, depending upon the size of the clamp. B should be made of cast steel. The slot admits a bolt at T which can be slipped anywhere along the clamp.

General Tables.

In order to successfully compete in any line of work, we must take short cuts by eliminating all unnecessary work. Consequently we are constantly resorting to tables in order to save ourselves an enormous amount of time and energy in calculations. Take for instance table number 1, which represents the areas and circumferences of circles. There is, perhaps, no table which is more frequently used in boiler work. The area and circumference is given for $^1/_{64}$, $^2/_{64}$, $^4/_{16}$, etc., up to one inch and then advances in quarters to 100 inches.

By using this table one can readily obtain the circumference of any diameter between $^1/_{64}$ of an inch and 100 inches, advancing by 64ths. For example we wish the circumference of $51^{63}/_{64}$ inches diameter.

Circumference of	51 inch =	160.222
	$^{15}/_{16}$ inch =	2.94525
	$^1/_{32}$ inch =	.09818
	$^1/_{64}$ inch =	.04909
	$51^{63}/_{64}$ inches =	163.31452

Or we can take the circumference of a 52-inch circle 163.363 and deduct .04909 from it.

General tables.

Another table which is very useful in saving time is table two, the logarithms of numbers. This table is used in operations in multiplication, division, and in the powers of numbers. Its use will best be understood by several examples.

(1) $\frac{173 \times 317}{131}$

$$\text{Log}\left(\frac{173 \times 317}{131}\right) = \text{Log } 173 + \text{Log } 317 - \text{Log } 131$$

Now hunt up 17 in the first column and 3 in the top column, the intersection gives 2.23804. The constant 2 is always one less than the number of figures.

We then have	Log 173 =	2.23804
Similarly	Log 317 =	2.50105
		4.73909
Minus Log of	131 =	2.11727
		2.62182

The number corresponding to this logarithm is found thus, from the table:

62221 = Log 419
62118 = Log 418

103 = difference

62182
62118

64

$\frac{64}{103}$ of 10 = 6

Therefore the number corresponding to 2.62182 = 418.6

Another useful table is table three. If we have an angle of say 40 degrees, Fig.332, and wish to know the side T, then A is 65 inches. Refer to table three and find the tangent of 40 degrees, equal to .8391, and this multiplied by 65 gives 54.5415 for the length of T. If on the other hand we knew what T was, from this table we could obtain what the angle opposite to T must be.

In a similar way, from table four, we can find the co-tangent and from the table we could obtain the sine and cosine of different angles.

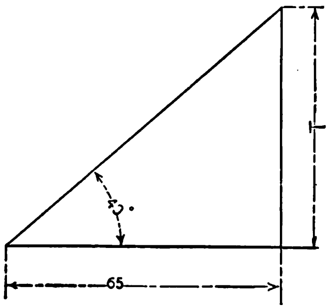


Figure 332
Showing angles.

In finding the weight of water in boilers, we know the distance from the water level or the top gage cock, to the top line of the boiler. See H, Fig. 333. We also know the inside diameter of the boiler D and the length L for the different sheets. In obtaining the area of the segment H, we use table five.

General tables.

Area of segment $= D^2 \times M$

$$M = \frac{H}{D} = \frac{14}{68} = .206$$

The value for M corresponding to .206 is found to be .116651 by reference to table five.

Therefore segment area $= D^2 \times .1116651$

$$= 68^2 \times .1116651 = 541$$

The volume of the water in the boiler in gallons would be

$$= \frac{(68 \text{ area} - \text{Segment area}) \times L}{231}$$

$$= \frac{(3632 - 541) \times L}{231} = \frac{3091 \times 116}{231}$$

$= 1553$ gallons.

In a similar manner each one of the other courses can be calculated.

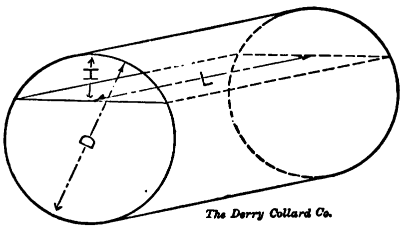


Figure 333

Areas of segments.

Strength of materials.

Table six gives the properties of saturated steam from one to 1,000 pounds pressure. This is useful in determining the expansion of a boiler. The temperature of the boiler plate is obtained from the table by finding the temperature corresponding to the working pressure and then figuring out the expansion by the use of another table.

Strength of Materials.

The tensile strength of bolts is given in table seven. If we have a bolt 1¼ inches in diameter and wish to support 5,000 lbs., the stress in this bolt will be about 7,000, and similarly if we decide what stress is allowable in a given bolt, we can find what pull the bolt will resist from the table.

The breaking strength of bolts is considerably higher than the working strength, in fact it is four or five times higher as will be noticed by referring to table eight. These figures are useful as they represent the pull at which the bolt will be broken.

All the pins, bolts, etc., in a boiler which are to resist a bending action should be designed to meet these requirements. Table nine represents the maximum bending moment on pins at various fibre stresses. Let us suppose that we have a pin P, Fig. 336, upon which there is acting a thrust T, ot 9,000 lbs. We wish to know what size pin to put in to resist this thrust. We will suppose that L is 5 inches, the bending moment will be

$$\frac{WL}{4} = \frac{9000 \times 5}{4} = 11250$$

Now referring to table nine, we find in the third column 11780, and the diameter corresponding to it is two inches. We will therefore use a 2-inch pin. If a higher stress is desired another diameter can be picked out from the stresses given in this table.

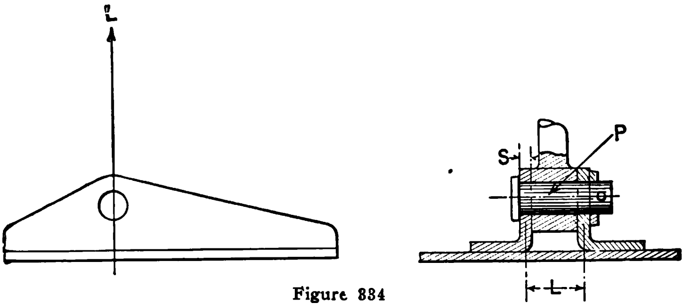


Figure 834
Strength of bolts.

Another thing to be considered in connection with the strength of the bolt is the bearing that the bolt has in the plates S, Fig. 334. In this particular case it would be $\frac{3}{8}$ of an inch thick and the area would be $\frac{3}{8} \times 2 \times 2 = 1\frac{1}{2}$ inches which would be perfectly safe. If the plates were very thin however, let us say a 1-inch bolt and two $\frac{1}{4}$-inch plates, the area would be $\frac{1}{2}$ inch, which would give a fiber stress of 18,000 lbs., which would be too much. We would therefore have $1\frac{1}{2}$-inch pin, which table 10 tells us gives a bearing value of 12,000 lbs. and which would be safe.

The values of the moments of inertia for sections which are commonly used are noted in table 11, also the moment of resistance for the same section. It is sometimes necessary to know the deflection of plates of various kinds in connection with the boiler. The kind of beam, condition of loading, maximum bending moment, deflection, etc., are all put in convenient form for reference in table 12.

The thicknesses of the boiler shell for different diameters and for different conditions of riveting are given in table 13. This table is convenient in deciding the thickness of the plates which are to be used under the different conditions of the boiler and pressure which it is to work.

The thickness of the plates for corrugated furnaces like the Vanderbilt type, can be obtained from table 14.

Table 15 is given so as to enable one to see the different conditions specified for fire box steel by some of the most prominent railroads and locomotive shops.

Equivalents.

The figures in table 16 represent the decimal equivalent of 32nds, 64ths and other fractions of an inch as noted. This table is too frequently used to require any special mention.

In determining the number of square feet in plates, table 17 will be found convenient in order to reduce fractions of a square foot into square inches.

In a similar manner, table 18 is useful in comparing sq. inches with decimal fractions of a sq. ft., length in inches can be reduced to decimal fractions of a foot by using figures given in table 19.

The coefficients of linear expansion for a number of substances in common use are noted in table 20. Let us suppose that we wish to know how much a boiler 25 ft. long would expand with a rise of temperature of 350 degrees Fahr. In table 20 for steel, we find the coefficient equal .0000060. The expansion therefore would be $.0000060 \times 350 \times 25 \times 12 = .63$, which we find is a little greater than 5/8 of an inch.

Size of Materials.

The U. S. standard screw thread and nuts are given in table 21, varying from 1/4 inch in diameter to 4 inches in diameter and includes about everything that will be used about a boiler.

Table 22 gives the diameter for lap welded locomotive boiler tubes varying from one inch to four inches in diameter. The length of the tubes per sq. ft. of external and internal surfaces is useful in calculating the heating surface of boilers. The diameters for the standard plate washers are given in table 24.

Table 23 represents the standard diameter for wrought iron, welded, steam, gas, and water pipe.

The standard sizes for tank rivets are given in table 25, while table 26 represents the same thing for boiler rivets.

Weights.

The weight of steel plates per sq. ft. from 1/16 to 1 3/4 inches in thickness are noted in table 27.

The allowance which must be made in the width of the dome plate where the dome flanges curve down to the radius of the boiler, is given in table 28.

It is a well known fact that all boiler plates are thicker in the center than they are along the edges of the plate. This is due to the fact that the rolls have been bent when the sheet was run through the mill. On this account plates always overrun in weight and the amount is noted in per cent. in table 29, for the various widths and thickness of the plate.

The weights of circular plates are given in table 30. The thinner plates are usually carried by plate gages. Table 31 gives the figures for the weight per sq. ft. for iron, steel, copper, and brass to suit the gage. It also shows the thickness in decimals and fractions of an inch corresponding to the different gages mentioned.

As much round and square iron is used on a boiler, Table 32 gives the weight per ft. The sizes range from $^{3}/_{16}$ to $3^{15}/_{16}$ in either round or square.

As there is also a great deal of flat iron used, the width in inches of the iron has been grouped in the first column, Table 33, and the thickness along the top column. The weight per lineal foot is read off from the intersection of the two columns.

In table 34 we have the estimated weights for different commercial size sheets, while table 35 gives the weight per lineal foot of different size steel angles corresponding to the given thickness in inches.

The number of rivets in 100 lbs., when the size and the length of the rivets are known, is given in table 36.

Table 37 represents the weight of one cubic foot of water at various temperatures. The figures here given are important in estimating the weight of a boiler under working conditions, for as the water expands as the temperature rises it naturally weighs less per cubic foot. The difference between the weight at 32 degrees and

390 degrees Fahr. is readily seen in the table and must be considered in calculations.

Boilers for foreign customers very often have dimensions given in the metric system, and tables 38, 39 and 40 will be found very useful in this connection.

Table No. 1.

Areas and Circumferences of Circles From 1-64th to 100.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
1/64	.000192	.04909	6 3/4	35.7848	21.2058
1/32	.000767	.09818	7	38.4846	21.9912
1/16	.003068	.19635	1/4	41.2826	22.7766
1/8	.012272	.3927	1/2	44.1787	23.562
3/16	.027612	.589	3/4	47.1731	24.3474
1/4	.049087	.7854	8	50.2656	25.1328
5/16	.076699	.98175	1/4	53.4563	25.9182
3/8	.110447	1.1781	1/2	56.7451	26.7036
7/16	.15033	1.37445	3/4	60.1322	27.489
1/2	.19635	1.5708	9	63.6174	28.2744
9/16	.248505	1.76715	1/4	67.2008	29.0598
5/8	.306796	1.9635	1/2	70.8823	29.8452
11/16	.371224	2.15985	3/4	74.6621	30.6306
3/4	.441787	2.3562	10	78.54	31.416
13/16	.518487	2.55255	1/4	82.5161	32.2014
7/8	.601322	2.7489	1/2	86.5903	32.9868
15/16	.690292	2.94525	3/4	90.7628	33.7722
1	.7854	3.1416	11	95.0334	34.5576
1/4	1.2272	3.927	1/4	99.4022	35.343
1/2	1.7671	4.7124	1/2	103.8691	36.1284
3/4	2.4053	5.4978	3/4	108.4343	36.9138
2	3.1416	6.2832	12	113.098	37.6992
1/4	3.9761	7.0686	1/4	117.859	38.4846
1/2	4.9087	7.854	1/2	122.719	39.27
3/4	5.9396	8.6384	3/4	127.677	40.0554
3	7.0686	9.4248	13	132.733	40.8408
1/4	8.2958	10.2102	1/4	137.887	41.6262
1/2	9.6211	10.9956	1/2	143.139	42.4116
3/4	11.0447	11.781	3/4	148.49	43.197
4	12.5664	12.5664	14	153.938	43.9824
1/4	14.1863	13.3518	1/4	159.485	44.7678
1/2	15.9043	14.1372	1/2	165.13	45.5532
3/4	17.7206	14.9226	3/4	170.874	46.3386
5	19.635	15.708	15	176.715	47.124
1/4	21.6476	16.4934	1/4	182.655	47.9094
1/2	23.7583	17.2788	1/2	188.692	48.6948
3/4	25.9673	18.0642	3/4	194.828	49.4802
6	28.2744	18.8496	16	201.062	50.2656
1/4	30.6797	19.635	1/4	207.395	51.051
1/2	33.1831	20.4204	1/2	213.825	51.8364

Areas and Circumferences of Circles
(*Continued*).

Diam.	Area.	Circum.	Diam.	Area.	Circum.
16¾	220.354	52.6218	28	615.754	87.9648
17	226.981	53.4072	¼	626.798	88.7502
¼	233.706	54.1926	½	637.941	89.5356
½	240.529	54.978	¾	649.182	90.321
¾	247.45	55.7634	29	660.521	91.1064
18	254.47	56.5488	¼	671.959	91.8918
¼	261.587	57.3342	½	683.494	92.6772
½	268.803	58.1196	¾	695.128	93.4626
¾	276.117	58.905	30	706.86	94.248
19	283.529	59.6904	¼	718.69	95.0334
¼	291.04	60.4758	½	730.618	95.8188
½	298.648	61.2612	¾	742.645	96.6042
¾	306.355	62.0466	31	754.769	97.3896
20	314.16	62.832	¼	766.992	98.175
¼	322.063	63.6174	½	779.313	98.9604
½	330.064	64.4028	¾	791.732	99.7458
¾	338.164	65.1882	32	804.25	100.5312
21	346.361	65.9736	¼	816.865	101.3166
¼	354.657	66.759	½	829.579	102.102
½	363.051	67.5444	¾	842.391	102.8874
¾	371.543	68.3298	33	855.301	103.673
22	380.134	69.1152	¼	868.309	104.458
¼	388.822	69.9006	½	881.415	105.244
½	397.609	70.686	¾	894.62	106.029
¾	406.494	71.4714	34	907.922	106.814
23	415.477	72.2568	¼	921.323	107.6
¼	424.558	73.0422	½	934.822	108.385
½	433.737	73.8276	¾	948.42	109.171
¾	443.015	74.613	35	962.115	109.956
24	452.39	75.3984	¼	975.909	110.741
¼	461.864	76.1838	½	989.8	111.527
½	471.436	76.9692	¾	1003.79	112.312
¾	481.107	77.7546	36	1017.878	113.098
25	490.875	78.54	¼	1032.065	113.883
¼	500.742	79.3254	½	1046.349	114.668
½	510.706	80.1108	¾	1060.732	115.454
¾	520.769	80.8962	37	1075.213	116.239
26	530.93	81.6816	¼	1089.792	117.025
¼	541.19	82.467	½	1104.469	117.81
½	551.547	83.2524	¾	1119.244	118.595
¾	562.003	84.0378	38	1134.118	119.381
27	572.557	84.8232	¼	1149.089	120.166
¼	583.209	85.6086	½	1164.159	120.952
½	593.959	86.394	¾	1179.327	121.737
¾	604.807	87.1794	39	1194.593	122.522

Areas and Circumferences of Circles

(Continued).

Diam.	Area.	Circum.	Diam.	Area.	Circum.
39¼	1209.958	123.308	50½	2002.97	158.651
½	1225.42	124.093	¾	2022.85	159.436
¾	1240.981	124.879	51	2042.83	160.222
40	1256.64	125.664	¼	2062.9	161.007
¼	1272.397	126.449	½	2083.08	161.792
½	1288.252	127.235	¾	2103.35	162.578
¾	1304.206	128.02	52	2123.72	163.363
41	1320.257	128.806	¼	2144.19	164.149
¼	1336.407	129.591	½	2164.76	164.934
½	1352.655	130.376	¾	2185.42	165.719
¾	1339.001	131.162	53	2206.19	166.505
42	1385.45	131.947	¼	2227.05	167.29
¼	1401.99	132.733	½	2248.01	168.076
½	1418.63	133.518	¾	2269.07	168.861
¾	1435.37	134.303	54	2290.23	169.646
43	1452.2	135.089	¼	2311.48	170.432
¼	1469.14	135.874	½	2332.83	171.217
½	1486.17	136.66	¾	2354.29	172.003
¾	1503.3	137.445	55	2375.83	172.788
44	1520.53	138.23	¼	2397.48	173.573
¼	1537.86	139.016	½	2419.23	174.359
½	1555.29	139.801	¾	2441.07	175.144
¾	1572.81	140.587	56	2463.01	175.93
45	1590.43	141.372	¼	2485.05	176.715
¼	1608.16	142.157	½	2507.19	177.5
½	1625.97	142.943	¾	2529.43	178.286
¾	1643.89	143.728	57	2551.76	179.071
46	1661.91	144.514	¼	2574.2	179.857
¼	1680.02	145.299	½	2596.73	180.642
½	1698.23	146.084	¾	2619.36	181.427
¾	1716.54	146.87	58	2642.09	182.213
47	1734.95	147.655	¼	2664.91	182.998
¼	1753.45	148.441	½	2687.84	183.784
½	1772.06	149.226	¾	2710.86	184.569
¾	1790.76	150.011	59	2733.98	185.354
48	1809.56	150.797	¼	2757.2	186.14
¼	1828.46	151.582	½	2780.51	186.925
½	1847.46	152.368	¾	2803.93	187.711
¾	1866.55	153.153	60	2827.44	188.496
49	1885.75	153.938	¼	2851.05	189.281
¼	1905.04	154.724	½	2874.76	190.067
½	1924.43	155.509	¾	2898.57	190.852
¾	1943.91	156.295	61	2922.47	191.638
50	1963.5	157.08	¼	2946.48	192.423
¼	1983.18	157.865	½	2970.58	193.208

Areas and Circumferences of Circles

(*Continued*).

Diam.	Area.	Circum.	Diam.	Area.	Circum.
61¾	2994.78	193.994	73	4185.4	229.337
62	3019.08	194.779	¼	4214.11	230.122
¼	3043.47	195.565	½	4242.93	230.908
½	3067.97	196.35	¾	4271.84	231 693
¾	3092.56	197.135	74	4300.85	232.478
63	3117.25	197.921	¼	4329.96	233.264
¼	3142.04	198.706	½	4359.17	234.049
½	3166.93	199.492	¾	4388.47	234.835
¾	3191.91	200.277	75	4417.87	235.62
64	3217.	201.062	¼	4447.38	236.405
¼	3242.18	201.848	½	4476.98	237.191
½	3267.46	202.633	¾	4506.67	237.976
¾	3292.84	203.419	76	4536.47	238.762
65	3318.31	204.204	¼	4566.36	239.547
¼	3343.89	204.989	½	4596.36	240.332
½	3369.56	205.775	¾	4626.45	241.118
¾	3395.33	206.56	77	4656.64	241.903
66	3421.2	207.346	¼	4686.92	242.689
¼	3447.17	208.131	½	4717.31	243.474
½	3473.24	208.916	¾	4747.79	244.259
¾	3499.4	209.702	78	4778.37	245.045
67	3525.66	210.487	¼	4809.05	245.83
¼	3552.02	211.273	½	4839.83	246.616
½	3578.48	212.058	¾	4870.71	247.401
¾	3605.04	212.843	79	4901.68	248.186
68	3631.69	213.629	¼	4932.75	248.972
¼	3658.44	214.414	½	4963.92	249.757
½	3685.29	215.2	¾	4995.19	250.543
¾	3712.24	215.985	80	5026.56	251.328
69	3739.29	216.77	¼	5058.03	252.113
¼	3766.43	217.556	½	5089.59	252.899
½	3793.68	218.341	¾	5121.25	253.684
¾	3821.02	219.127	81	5153.01	254.47
70	3848.46	219.912	¼	5184.87	255.255
¼	3876.	220.697	½	5216.82	256.04
½	3903.63	221.483	¾	5218.88	256.826
¾	3931.37	222.268	82	5281.03	257.611
71	3959.2	223.054	¼	5313.28	258.397
¼	3987.13	223.839	½	5345.63	259.182
½	4015.16	224.624	¾	5378.08	259.967
¾	4043.29	225.41	83	5410.62	260.753
72	4071.51	226.195	¼	5443.26	261.538
¼	4099.84	226.981	½	5476.01	262.324
½	4128.26	227.766	¾	5508.84	263.109
¾	4156.78	228.551	84	5541.78	263.894

Areas and Circumferences of Circles (*Concluded*).

Diam.	Area.	Circum.	Diam.	Area.	Circum.
84¼	5574.82	264.68	92¾	6756.45	291.383
½	5607.95	265.465	93	6792.92	292.169
¾	5641.18	266.251	¼	6829.49	292.954
85	5674.51	267.036	½	6866.16	293.74
¼	5707.94	267.821	¾	6902.93	294.525
½	5741.47	268.607	94	6939.79	295.31
¾	5775.1	269.392	¼	6976.76	296.096
86	5808.82	270.178	½	7013.82	296.881
¼	5842.64	270.963	¾	7050.98	297.667
½	5876.56	271.748	95	7088.23	298.452
¾	5910.58	272.534	¼	7125.59	299.237
87	5944.69	273.319	½	7163.04	300.023
¼	5978.91	274.105	¾	7200.6	300.808
½	6013.22	274.89	96	7238.25	301.594
¾	6047.63	275.675	¼	7275.99	302.379
88	6082.14	276.461	½	7313.84	303.164
¼	6116.74	277.246	¾	7351.79	303.95
½	6151.45	278.032	97	7389.83	304.735
¾	6186.25	278.817	¼	7427.97	305.521
89	6221.15	279.602	½	7466.21	306.306
¼	6256.15	280.388	¾	7504.55	307.091
½	6291.25	281.173	98	7542.98	307.877
¾	6326.45	281.959	¼	7581.52	308.662
90	6361.74	282.744	½	7620.15	309.448
¼	6397.13	283.529	¾	7658.88	310.233
½	6432.62	284.315	99	7697.71	311.018
¾	6468.21	285.1	¼	7736.63	311.804
91	6503.9	285.886	½	7775.66	312.589
¼	6539.68	286.671	¾	7814.78	313.375
½	6575.56	287.456	100	7854.	314.16
¾	6611.55	288.242	¼	7893.32	314.945
92	6647.63	289.027	½	7932.74	315.731
¼	6683.8	289.813	¾	7972.25	316.516
½	6720.08	290.598	.	....	....

Table No. 2.

Logarithms of Numbers, from 0 to 1000.

No.	0	1	2	3	4	5	6	7	8	9
0	0	00000	30103	47712	60206	69897	77815	84510	90309	95424
10	00000	00432	00860	01283	01703	02118	02530	02938	03342	03742
11	04139	04532	04921	05307	05690	06069	06445	06818	07188	07554
12	07918	08278	08636	08990	09342	09691	10037	10380	10721	11059
13	11394	11727	12057	12385	12710	13033	13353	13672	13987	14301
14	14613	14921	15228	15533	15836	16136	16435	16731	17026	17318
15	17609	17897	18184	18469	18752	19033	19312	19590	19865	20139
16	20412	20682	20951	21218	21484	21748	22010	22271	22530	22788
17	23045	23299	23552	23804	24054	24303	24551	24797	25042	25285
18	25527	25767	26007	26245	26481	26717	26951	27184	27415	27646
19	27875	28103	28330	28555	28780	29003	29225	29446	29666	29885
20	30103	30319	30535	30749	30963	31175	31386	31597	31806	32014
21	32222	32428	32633	32838	33041	33243	33445	33646	33845	34044
22	34242	34439	34635	34830	35024	35218	35410	35602	35793	35983
23	36173	36361	36548	36735	36921	37106	37291	37474	37657	37839
24	38021	38201	38381	38560	38739	38916	39093	39269	39445	39619
25	39794	39967	40140	40312	40483	40654	40824	40993	41162	41330
26	41497	41664	41830	41995	42160	42324	42488	42651	42813	42975
27	43136	43296	43456	43616	43775	43933	44090	44248	44404	44560
28	44716	44870	45024	45178	45331	45484	45636	45788	45939	46089
29	46240	46389	46538	46686	46834	46982	47129	47275	47421	47567
30	47712	47856	48000	48144	48287	48430	48572	48713	48855	48995
31	49136	49276	49415	49554	49693	49831	49968	50105	50242	50379
32	50515	50650	50785	50920	51054	51188	51321	51454	51587	51719
33	51851	51982	52113	52244	52374	52504	52633	52763	52891	53020
34	53148	53275	53402	53529	53655	53781	53907	54033	54157	54282
35	54407	54530	54654	54777	54900	55022	55145	55266	55388	55509
36	55630	55750	55870	55990	56110	56229	56348	56466	56584	56702
37	56820	56937	57054	57170	57287	57403	57518	57634	57749	57863
38	57978	58092	58206	58319	58433	58546	58658	58771	58883	58995
39	59106	59217	59328	59439	59549	59659	59769	59879	59988	60097
40	60206	60314	60422	60530	60638	60745	60852	60959	61066	61172
41	61278	61384	61489	61595	61700	61804	61909	62013	62118	62221
42	62325	62428	62531	62634	62736	62838	62941	63042	63144	63245
43	63347	63447	63548	63648	63749	63848	63948	64048	64147	64246
44	64345	64443	64542	64640	64738	64836	64933	65030	65127	65224
45	65321	65417	65513	65609	65705	65801	65896	65991	66086	66181
46	66276	66370	66464	66558	66651	66745	66838	66931	67024	67117
47	67210	67302	67394	67486	67577	67669	67760	67851	67942	68033
48	68124	68214	68304	68394	68484	68574	68663	68752	68842	68930
49	69020	69108	69196	69284	69372	69460	69548	69635	69722	69810
50	69897	69983	70070	70156	70243	70329	70415	70500	70586	70671
51	70757	70842	70927	71011	71096	71180	71265	71349	71433	71516
52	71600	71683	71767	71850	71933	72015	72098	72181	72263	72345
53	72428	72509	72591	72672	72754	72835	72916	72997	73078	73158
54	73239	73319	73399	73480	73559	73639	73719	73798	73878	73957

Logarithms of Numbers, from 0 to 1000.

(*Continued*).

No.	0	1	2	3	4	5	6	7	8	9
55	74036	74115	74193	74272	74351	74429	74507	74585	74663	74741
56	74818	74896	74973	75050	75127	75204	75281	75358	75434	75511
57	75587	75663	75739	75815	75891	75966	76042	76117	76192	76267
58	76342	76417	76492	76566	76641	76715	76789	76863	76937	77011
59	77085	77158	77232	77305	77378	77451	77524	77597	77670	77742
60	77815	77887	77959	78031	78103	78175	78247	78318	78390	78461
61	78533	78604	78675	78746	78816	78887	78958	79028	79098	79169
62	79239	79309	79379	79448	79518	79588	79657	79726	79796	79865
63	79934	80002	80071	80140	80208	80277	80345	80413	80482	80550
64	80618	80685	80753	80821	80888	80956	81023	81090	81157	81224
65	81291	81358	81424	81491	81557	81624	81690	81756	81822	81888
66	81954	82020	82085	82151	82216	82282	82347	82412	82477	82542
67	82607	82672	82736	82801	82866	82930	82994	83058	83123	83187
68	83250	83314	83378	83442	83505	83569	83632	83695	83758	83821
69	83884	83947	84010	84073	84136	84198	84260	84323	84385	84447
70	84509	84571	84633	84695	84757	84818	84880	84941	85003	85064
71	85125	85187	85248	85309	85369	85430	85491	85551	85612	85672
72	85733	85793	85853	85913	85973	86033	86093	86153	86213	86272
73	86332	86391	86451	86510	86569	86628	86687	86746	86805	86864
74	86923	86981	87040	87098	87157	87215	87273	87332	87390	87448
75	87506	87564	87621	87679	87737	87794	87852	87909	87966	88024
76	88081	88138	88195	88252	88309	88366	88422	88479	88536	88592
77	88649	88705	88761	88818	88874	88930	88986	89042	89098	89153
78	89209	89265	89320	89376	89431	89487	89542	89597	89652	89707
79	89762	89817	89872	89927	89982	90036	90091	90145	90200	90254
80	90309	90363	90417	90471	90525	90579	90633	90687	90741	90794
81	90848	90902	90955	91009	91062	91115	91169	91222	91275	91328
82	91381	91434	91487	91540	91592	91645	91698	91750	91803	91855
83	91907	91960	92012	92064	92116	92168	92220	92272	92324	92376
84	92427	92479	92531	92582	92634	92685	92737	92788	92839	92890
85	92941	92993	93044	93095	93146	93196	93247	93298	93348	93399
86	93449	93500	93550	93601	93651	93701	93751	93802	93852	93902
87	93951	94001	94051	94101	94151	94200	94250	94300	94349	94398
88	94448	94497	94546	94596	94645	94694	94743	94792	94841	94890
89	94939	94987	95036	95085	95133	95182	95230	95279	95327	95376
90	95424	95472	95520	95568	95616	95664	95712	95760	95808	95856
91	95904	95951	95999	96047	96094	96142	96189	96236	96284	96331
92	96378	96426	96473	96520	96567	96614	96661	96708	96754	96801
93	96848	96895	96941	96988	97034	97081	97127	97174	97220	97266
94	97312	97359	97405	97451	97497	97543	97589	97635	97680	97726
95	97772	97818	97863	97909	97954	98000	98045	98091	98136	98181
96	98227	98272	98317	98362	98407	98452	98497	98542	98587	98632
97	98677	98721	98766	98811	98855	98900	98945	98989	99033	99078
98	99122	99166	99211	99255	99299	99343	99387	99431	99475	99519
99	99563	99607	99651	99694	99738	99782	99825	99869	99913	99956

TABLE No. 3.

Natural Tangents.

Deg.	0′	10′	20′	30′	40′	50′	Deg.
0	0000	0029	0058	0087	0116	0145	89
1	0175	0204	0233	0262	0291	0320	88
2	0349	0378	0407	0437	0466	0495	87
3	0524	0553	0582	0612	0641	0670	86
4	0699	0729	0758	0787	0816	0846	85
5	0875	0904	0934	0963	0992	1022	84
6	1051	1080	1110	1139	1169	1198	83
7	1228	1257	1287	1317	1346	1376	82
8	1405	1435	1465	1495	1524	1554	81
9	1584	1614	1644	1673	1703	1733	80
10	1763	1793	1823	1853	1883	1914	79
11	1944	1974	2004	2035	2065	2095	78
12	2126	2156	2186	2217	2247	2278	77
13	2309	2339	2370	2401	2432	2462	76
14	2493	2524	2555	2586	2617	2648	75
15	2679	2711	2742	2773	2805	2836	74
16	2867	2899	2931	2962	2994	3026	73
17	3057	3089	3121	3153	3185	3217	72
18	3249	3281	3314	3346	3378	3411	71
19	3443	3476	3508	3541	3574	3607	70
20	3640	3673	3706	3739	3772	3805	69
21	3839	3872	3906	3939	3973	4006	68
22	4040	4074	4108	4142	4176	4210	67
23	4245	4279	4314	4348	4383	4417	66
24	4452	4487	4522	4557	4592	4628	65
25	4663	4699	4734	4770	4806	4841	64
26	4877	4913	4950	4986	5022	5059	63
27	5095	5132	5169	5206	5243	5280	62
28	5317	5354	5392	5430	5467	5505	61
29	5543	5581	5619	5658	5696	5735	60
30	5774	5812	5851	5890	5930	5969	59
31	6009	6048	6088	6128	6168	6208	58
32	6249	6289	6330	6371	6412	6453	57
33	6494	6536	6577	6619	6661	6703	56
34	6745	6787	6830	6873	6916	6959	55
35	7002	7046	7089	7133	7177	7221	54
36	7265	7310	7355	7400	7445	7490	53
37	7536	7581	7627	7673	7720	7766	52
38	7813	7860	7907	7954	8002	8050	51
39	8098	8146	8195	8243	8292	8342	50
Deg.	60′	50′	40′	30′	20′	10′	Deg.

Natural Cotangents.

Natural Tangents (*Continued*).

Deg.	0′	10′	20′	30′	40′	50′	Deg.
40	8391	8441	8491	8541	8591	8642	49
41	8693	8744	8796	8847	8899	8952	48
42	9004	9057	9110	9163	9217	9271	47
43	9325	9380	9435	9490	9545	9601	46
44	9657	9713	9770	9827	9884	9942	45
45	1.0000	1.0058	1.0117	1.0176	1.0235	1.0295	44
46	1.0355	1.0416	1.0477	1.0538	1.0599	1.0661	43
47	1.0724	1.0786	1.0850	1.0913	1.0977	1.1041	42
48	1.1106	1.1171	1.1237	1.1303	1.1369	1.1436	41
49	1.1504	1.1571	1.1640	1.1708	1.1778	1.1847	40
50	1.1918	1.1988	1.2059	1.2131	1.2203	1.2276	39
51	1.2349	1.2423	1.2497	1.2572	1.2647	1.2723	38
52	1.2799	1.2876	1.2954	1.3032	1.3111	1.3190	37
53	1.3270	1.3351	1.3432	1.3514	1.3597	1.3680	36
54	1.3764	1.3848	1.3934	1.4019	1.4106	1.4193	35
55	1.4281	1.4370	1.4460	1.4550	1.4641	1.4733	34
56	1.4826	1.4919	1.5013	1.5108	1.5204	1.5301	33
57	1.5399	1.5497	1.5597	1.5697	1.5798	1.5900	32
58	1.6003	1.6107	1.6212	1.6319	1.6426	1.6534	31
59	1.6643	1.6753	1.6864	1.6977	1.7090	1.7205	30
60	1.7321	1.7437	1.7556	1.7675	1.7796	1.7917	29
61	1.8040	1.8165	1.8291	1.8418	1.8546	1.8676	28
62	1.8807	1.8940	1.9074	1.9210	1.9347	1.9486	27
63	1.9626	1.9768	1.9912	2.0057	2.0204	2.0353	26
64	2.0503	2.0655	2.0809	2.0965	2.1123	2.1283	25
65	2.1445	2.1609	2.1775	2.1943	2.2113	2.2286	24
66	2.2460	2.2637	2.2817	2.2998	2.3183	2.3369	23
67	2.3559	2.3750	2.3945	2.4142	2.4342	2.4545	22
68	2.4751	2.4960	2.5172	2.5386	2.5605	2.5826	21
69	2.6051	2.6279	2.6511	2.6746	2.6985	2.7228	20
70	2.7475	2.7725	2.7980	2.8239	2.8502	2.8770	19
71	2.9042	2.9319	2.9600	2.9887	3.0178	3.0475	18
72	3.0777	3.1084	3.1397	3.1716	3.2041	3.2371	17
73	3.2709	3.3052	3.3402	3.3759	3.4124	3.4495	16
74	3.4874	3.5261	3.5656	3.6059	3.6470	3.6891	15
75	3.7321	3.7760	3.8208	3.8667	3.9136	3.9617	14
76	4.0108	4.0611	4.1126	4.1653	4.2193	4.2747	13
77	4.3315	4.3897	4.4494	4.5107	4.5736	4.6382	12
78	4.7046	4.7729	4.8430	4.9152	4.9894	5.0658	11
79	5.1446	5.2257	5.3093	5.3955	5.4845	5.5764	10
Deg.	60′	50′	40′	30′	20′	10′	Deg.

Natural Cotangents (*Continued*).

Natural Tangents (*Concluded*).

Deg.	0′	10′	20′	30′	40′	50′	Deg.
80	5.6713	5.7694	5.8708	5.9758	6.0844	6.1970	9
81	6.3138	6.4348	6.5606	6.6912	6.8269	6.9682	8
82	7.1154	7.2687	7.4287	7.5958	7.7704	7.9530	7
83	8.1443	8.3450	8.5555	8.7769	9.0098	9.2553	6
84	9.5144	9.7882	10.0780	10.3854	10.7119	11.0594	5
85	11.4301	11.8262	12.2505	12.7062	13.1969	13.7267	4
86	14.3007	14.9244	15.6048	16.3499	17.1693	18.0750	3
87	19.0811	20.2056	21.4704	22.9038	24.5418	26.4316	2
88	28.6363	31.2416	34.3678	38.1885	42.9641	49.1039	1
89	57.2900	68.7501	85.9398	114.5887	171.8854	343.7737	0
Deg.	60′	50′	40′	30′	20′	10′	Deg.

Natural Cotangents (*Concluded*).

Table No. 4.

Natural Sines.

Deg.	0'	10'	20'	30'	40'	50'	Deg.
0	0000	0029	0058	0087	0116	0145	89
1	0175	0204	0233	0262	0291	0320	88
2	0349	0378	0407	0436	0465	0494	87
3	0523	0552	0581	0610	0640	0669	86
4	0698	0727	0756	0785	0814	0843	85
5	0872	0901	0929	0958	0987	1016	84
6	1045	1074	1103	1132	1161	1190	83
7	1219	1248	1276	1305	1334	1363	82
8	1392	1421	1449	1478	1507	1536	81
9	1564	1593	1622	1650	1679	1708	80
10	1736	1765	1794	1822	1851	1880	79
11	1908	1937	1965	1994	2022	2051	78
12	2079	2108	2136	2164	2193	2221	77
13	2250	2278	2306	2334	2363	2391	76
14	2419	2447	2476	2504	2532	2560	75
15	2588	2616	2644	2672	2700	2728	74
16	2756	2784	2812	2840	2868	2896	73
17	2924	2952	2979	3007	3035	3062	72
18	3090	3118	3145	3173	3201	3228	71
19	3256	3283	3311	3338	3365	3393	70
20	3420	3448	3475	3502	3529	3557	69
21	3584	3611	3638	3665	3692	3719	68
22	3746	3773	3800	3827	3854	3881	67
23	3907	3934	3961	3987	4014	4041	66
24	4067	4094	4120	4147	4173	4200	65
25	4226	4253	4279	4305	4331	4358	64
26	4384	4410	4436	4462	4488	4514	63
27	4540	4566	4592	4617	4643	4669	62
28	4695	4720	4746	4772	4797	4823	61
29	4848	4874	4899	4924	4950	4975	60
30	5000	5025	5050	5075	5100	5125	59
31	5150	5175	5200	5225	5250	5275	58
32	5299	5324	5348	5373	5398	5422	57
33	5446	5471	5495	5519	5544	5568	56
34	5592	5616	5640	5664	5688	5712	55
35	5736	5760	5783	5807	5831	5854	54
36	5878	5901	5925	5948	5972	5995	53
37	6018	6041	6065	6088	6111	6134	52
38	6157	6180	6202	6225	6248	6271	51
39	6293	6316	6338	6361	6383	6406	50
Deg.	60'	50'	40'	30'	20'	10'	Deg.

Natural Cosines.

Natural Sines (*Continued*).

Deg.	0′	10′	20′	30′	40′	50′	Deg.
40	6428	6450	6472	6494	6517	6539	49
41	6561	6583	6604	6626	6648	6670	48
42	6691	6713	6734	6756	6777	6799	47
43	6820	6841	6862	6884	6905	6926	46
44	6947	6967	6988	7009	7030	7050	45
45	7071	7092	7112	7133	7153	7173	44
46	7193	7214	7234	7254	7274	7294	43
47	7314	7333	7353	7373	7392	7412	42
48	7431	7451	7470	7490	7509	7528	41
49	7547	7566	7585	7604	7623	7642	40
50	7660	7679	7698	7716	7735	7753	39
51	7771	7790	7808	7826	7844	7862	38
52	7880	7898	7916	7934	7951	7969	37
53	7986	8004	8021	8039	8056	8073	36
54	8090	8107	8124	8141	8158	8175	35
55	8192	8208	8225	8241	8258	8274	34
56	8290	8307	8323	8339	8355	8371	33
57	8387	8403	8418	8434	8450	8465	32
58	8480	8496	8511	8526	8542	8557	31
59	8572	8587	8601	8616	8631	8646	30
60	8660	8675	8689	8704	8718	8732	29
61	8746	8760	8774	8788	8802	8816	28
62	8829	8843	8857	8870	8884	8897	27
63	8910	8923	8936	8949	8962	8975	26
64	8988	9001	9013	9026	9038	9051	25
65	9063	9075	9088	9100	9112	9124	24
66	9135	9147	9159	9171	9182	9194	23
67	9205	9216	9228	9239	9250	9261	22
68	9272	9283	9293	9304	9315	9325	21
69	9336	9346	9356	9367	9377	9387	20
70	9397	9407	9417	9426	9436	9446	19
71	9455	9465	9474	9483	9492	9502	18
72	9511	9520	9528	9537	9546	9555	17
73	9563	9572	9580	9588	9596	9605	16
74	9613	9621	9628	9636	9644	9652	15
75	9659	9667	9674	9681	9689	9696	14
76	9703	9710	9717	9724	9730	9737	13
77	9744	9750	9757	9763	9769	9775	12
78	9781	9787	9793	9799	9805	9811	11
79	9816	9822	9827	9833	9838	9843	10
Deg.	60′	50′	40′	30′	20′	10′	Deg.

Natural Cosines (*Continued*).

Natural Sines (*Concluded*).

Deg.	0′	10′	20′	30′	40′	50′	Deg.
80	9848	9853	9858	9863	9868	9872	9
81	9877	9881	9886	9890	9894	9899	8
82	9903	9907	9911	9914	9918	9922	7
83	9925	9929	9932	9936	9939	9942	6
84	9945	9948	9951	9954	9957	9959	5
85	9962	9964	9967	9969	9971	9974	4
86	9976	9978	9980	9981	9983	9985	3
87	9986	9988	9989	9990	9992	9993	2
88	9994	9995	9996	9997	9997	9998	1
89	9998	9999	9999	9999	1.0000	1.0000	0
Deg.	60′	50′	40′	30′	20′	10′	Deg.

Natural Cosines (*Concluded*).

Table No. 5.

Areas of Segments of a Circle.

D=diameter of circle. H=Height of segment.

Area of segment=$D^2 \times M$. The following table gives values of M corresponding to various values of $\frac{H}{D}$.

$\frac{H}{D}$	M	$\frac{H}{D}$	M	$\frac{H}{D}$	M	$\frac{H}{D}$	M
.001	.000042	.040	.010538	.079	.028894	.118	.052090
.002	.000119	.041	.010932	.080	.029435	.119	.052737
.003	.000219	.042	.011331	.081	.029979	.120	.053385
.004	.000337	.043	.011734	.082	.030526	.121	.054037
.005	.000471	.044	.012142	.083	.031077	.122	.054690
.006	.000619	.045	.012555	.084	.031630	.123	.055346
.007	.000779	.046	.012971	.085	.032186	.124	.056004
.008	.000952	.047	.013393	.086	.032746	.125	.056664
.009	.001135	.048	.013818	.087	.033308	.126	.057326
.010	.001329	.049	.014248	.088	.033873	.127	.057991
.011	.001533	.050	.014681	.089	.034441	.128	.058658
.012	.001746	.051	.015119	.090	.035012	.129	.059328
.013	.001969	.052	.015561	.091	.035586	.130	.059999
.014	.002199	.053	.016008	.092	.036162	.131	.060673
.015	.002438	.054	.016458	.093	.036742	.132	.061349
.016	.002685	.055	.016912	.094	.037324	.133	.062027
.017	.002940	.056	.017369	.095	.037909	.134	.062707
.018	.003202	.057	.017831	.096	.038497	.135	.063389
.019	.003472	.058	.018297	.097	.039087	.136	.064074
.020	.003749	.059	.018766	.098	.039681	.137	.064761
.021	.004032	.060	.019239	.099	.040277	.138	.065449
.022	.004322	.061	.019716	.100	.040875	.139	.066140
.023	.004619	.062	.020197	.101	.041477	.140	.066833
.024	.004922	.063	.020681	.102	.042081	.141	.067528
.025	.005231	.064	.021168	.103	.042687	.142	.068225
.026	.005546	.065	.021660	.104	.043296	.143	.068924
.027	.005867	.066	.022155	.105	.043908	.144	.069626
.028	.006194	.067	.022653	.106	.044523	.145	.070329
.029	.006527	.068	.023155	.107	.045140	.146	.071034
.030	.006866	.069	.023660	.108	.045759	.147	.071741
.031	.007209	.070	.024168	.109	.046381	.148	.072450
.032	.007559	.071	.024680	.110	.047006	.149	.073162
.033	.007913	.072	.025196	.111	.047633	.150	.073875
.034	.008273	.073	.025714	.112	.048262	.151	.074590
.035	.008638	.074	.026236	.113	.048894	.152	.075307
.036	.009008	.075	.026761	.114	.049529	.153	.076026
.037	.009383	.076	.027290	.115	.050165	.154	.076747
.038	.009763	.077	.027821	.116	.050805	.155	.077470
.039	.010148	.078	.028356	.117	.051446	.156	.078194

Areas of Segments of a Circle (*Continued*).

$\frac{H}{D}$	M	$\frac{H}{D}$	M	$\frac{H}{D}$	M	$\frac{H}{D}$	M
.157	.078921	.200	.111824	.243	.147513	.286	.185425
.158	.079650	.201	.112625	.244	.148371	.287	.186329
.159	.080380	.202	.113427	.245	.149231	.288	.187235
.160	.081112	.203	.114231	.246	.150091	.289	.188141
.161	.081847	.204	.115036	.247	.150953	.290	.189048
.162	.082582	.205	.115842	.248	.151816	.291	.189956
.163	.083320	.206	.116651	.249	.152681	.292	.190865
.164	.084060	.207	.117460	.250	.153546	.293	.191774
.165	.084801	.208	.118271	.251	.154413	.294	.192685
.166	.085545	.209	.119083	.252	.155281	.295	.193597
.167	.086290	.210	.119898	.253	.156149	.296	.194509
.168	.087037	.211	.120713	.254	.157019	.297	.195423
.169	.087785	.212	.121530	.255	.157891	.298	.196337
.170	.088536	.213	.122348	.256	.158763	.299	.197252
.171	.089288	.214	.123167	.257	.159636	.300	.198168
.172	.090042	.215	.123988	.258	.160511	.301	.199085
.173	.090797	.216	.124811	.259	.161386	.302	.200003
.174	.091555	.217	.125634	.260	.162263	.303	.200922
.175	.092314	.218	.126459	.261	.163141	.304	.201841
.176	.093074	.219	.127286	.262	.164020	.305	.202762
.177	.093837	.220	.128114	.263	.164900	.306	.203683
.178	.094601	.221	.128943	.264	.165781	.307	.204605
.179	.095367	.222	.129773	.265	.166663	.308	.205528
.180	.096135	.223	.130605	.266	.167546	.309	.206452
.181	.096904	.224	.131438	.267	.168431	.310	.207376
.182	.097675	.225	.132273	.268	.169316	.311	.208302
.183	.098447	.226	.133109	.269	.170202	.312	.209228
.184	.099221	.227	.133946	.270	.171090	.313	.210155
.185	.099997	.228	.134784	.271	.171978	.314	.211083
.186	.100774	.229	.135624	.272	.172868	.315	.212011
.187	.101553	.230	.136465	.273	.173758	.316	.212941
.188	.102334	.231	.137307	.274	.174650	.317	.213871
.189	.103116	.232	.138151	.275	.175542	.318	.214802
.190	.103900	.233	.138996	.276	.176436	.319	.215734
.191	.104686	.234	.139842	.277	.177330	.320	.216666
.192	.105472	.235	.140689	.278	.178226	.321	.217600
.193	.106261	.236	.141538	.279	.179122	.322	.218534
.194	.107051	.237	.142388	.280	.180020	.323	.219469
.195	.107843	.238	.143239	.281	.180918	.324	.220404
.196	.108636	.239	.144091	.282	.181818	.325	.221341
.197	.109431	.240	.144945	.283	.182718	.326	.222278
.198	.110227	.241	.145800	.284	.183619	.327	.223216
.199	.111025	.242	.146655	.285	.184522	.328	.224154

Areas of Segments of a Circle (*Concluded*).

$\frac{H}{D}$	M	$\frac{H}{D}$	M	$\frac{H}{D}$	M	$\frac{H}{D}$	M
.329	.225094	.372	.266111	.415	.308110	.458	.350749
.330	.226034	.373	.267078	.416	.309056	.459	.351745
.331	.226964	.374	.268046	.417	.310082	.460	.352742
.332	.227916	.375	.269014	.418	.311068	.461	.353739
.333	.228858	.376	.269982	.419	.312055	.462	.354736
.334	.229801	.377	.270951	.420	.313042	.463	.355733
.335	.230745	.378	.271921	.421	.314029	.464	.356730
.336	.231689	.379	.272891	.422	.315017	.465	.357728
.337	.232634	.380	.273861	.423	.316005	.466	.358725
.338	.233580	.381	.274832	.424	.316993	.467	.359723
.339	.234526	.382	.275804	.425	.317981	.468	.360721
.340	.235473	.383	.276776	.426	.318970	.469	.361719
.341	.236421	.384	.277748	.427	.319959	.470	.362717
.342	.237369	.385	.278721	.428	.320949	.471	.363715
.343	.238319	.386	.279695	.429	.321938	.472	.364714
.344	.239268	.387	.280669	.430	.322928	.473	.365712
.345	.240219	.388	.281643	.431	.323919	.474	.366711
.346	.241170	.389	.282618	.432	.324909	.475	.367710
.347	.242122	.390	.283593	.433	.325900	.476	.368708
.348	.243074	.391	.284569	.434	.326891	.477	.369707
.349	.244027	.392	.285545	.435	.327883	.478	.370706
.350	.244980	.393	.286521	.436	.328874	.479	.371705
.351	.245935	.394	.287499	.437	.329866	.480	.372704
.352	.246890	.395	.288476	.438	.330858	.481	.373704
.353	.247845	.396	.289454	.439	.331851	.482	.374703
.354	.248801	.397	.290432	.440	.332843	.483	.375702
.355	.249758	.398	.291411	.441	.333836	.484	.376702
.356	.250715	.399	.292390	.442	.334829	.485	.377701
.357	.251673	.400	.293370	.443	.335823	.486	.378701
.358	.252632	.401	.294350	.444	.336816	.487	.379701
.359	.253591	.402	.295330	.445	.337810	.488	.380700
.360	.254551	.403	.296311	.446	.338804	.489	.381700
.361	.255511	.404	.297292	.447	.339799	.490	.382700
.362	.256472	.405	.298274	.448	.340793	.491	.383700
.363	.257433	.406	.299256	.449	.341788	.492	.384699
.364	.258395	.407	.300238	.450	.342783	.493	.385699
.365	.259358	.408	.301221	.451	.343778	.494	.386699
.366	.260321	.409	.302204	.452	.344773	.495	.387699
.367	.261285	.410	.303187	.453	.345768	.496	.388699
.368	.262249	.411	.304171	.454	.346764	.497	.389699
.369	.263214	.412	.305156	.455	.347760	.498	.390699
.370	.264179	.413	.306140	.456	.348756	.499	.391699
.371	.265145	.414	.307125	.457	.349752	.500	.392699

Circumferences of Circles.

D—diameter of circle. C—circumference of circle.

$$C = \pi D = 3{\cdot}141593 D.$$

$$D = \frac{C}{\pi} = {\cdot}31831 C.$$

The use of the tables of circumferences of circles may be extended by applying the following rule:—If the diameter be multiplied or divided by any number, the circumference must be multiplied or divided by the same number.

Thus,	Diameter $= D$.	Circumference $= C$.
	Diameter $= nD$.	Circumference $= nC$.
	Diameter $= \frac{D}{n}$.	Circumference $= \frac{C}{n}$.

Circumferences of Small Circles.

(Diameters Advancing by 64ths.)

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
1/64	.04909	17/64	.83449	33/64	1.6199	49/64	2.4053
1/32	.09817	9/32	.88357	17/32	1.6690	25/32	2.4544
3/64	.14726	19/64	.93266	35/64	1.7181	51/64	2.5035
1/16	.19635	5/16	.98175	9/16	1.7671	13/16	2.5525
5/64	.24544	21/64	1.0308	37/64	1.8162	53/64	2.6016
3/32	.29452	11/32	1.0799	19/32	1.8653	27/32	2.6507
7/64	.34361	23/64	1.1290	39/64	1.9144	55/64	2.6998
1/8	.39270	3/8	1.1781	5/8	1.9635	7/8	2.7489
9/64	.44179	25/64	1.2272	41/64	2.0126	57/64	2.7980
5/32	.49087	13/32	1.2763	21/32	2.0617	29/32	2.8471
11/64	.53996	27/64	1.3254	43/64	2.1108	59/64	2.8962
3/16	.58905	7/16	1.3744	11/16	2.1598	15/16	2.9452
13/64	.63814	29/64	1.4235	45/64	2.2089	61/64	2.9943
7/32	.68722	15/32	1.4726	23/32	2.2580	31/32	3.0434
15/64	.73631	31/64	1.5217	47/64	2.3071	63/64	3.0925
1/4	.78540	1/2	1.5708	3/4	2.3562	1	3.1416

TABLE No. 6.

PROPERTIES OF SATURATED STEAM.

Pressure, Temperature, Volume and Density.

(Haswell.)

Pressure per sq. in.	Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.	Volume of 1 Pound.	Density or Wt. of 1 Cubic Foot.
Lbs.	Ins.	Deg.	Deg.	Cu. Ft.	Lb.
1	2.04	102.1	1112.5	330.36	.003
2	4.07	126.3	1119.7	172.08	.0058
3	6.11	141.6	1124.6	117.52	.0085
4	8.14	153.1	1128.1	89.62	.0112
5	10.18	162.3	1130.9	72.66	.0138
6	12.22	170.2	1133.3	61.21	.0163
7	14.25	176.9	1135.3	52.94	.0189
8	16.29	182.9	1137.2	46.69	.0214
9	18.32	188.3	1138.8	41.79	.0239
10	20.36	193.3	1140.3	37.84	.0264
11	22.39	197.8	1141.7	34.63	.0289
12	24.43	202.	1143.	31.88	.0314
13	26.46	205.9	1144.2	29.57	.0338
14	28.51	209.6	1145.3	27.61	.0362
14.7	29.92	212.	1146.1	26.36	.03802
15	30.54	213.1	1146.4	25.85	.0387
16	32.57	216.3	1147.4	24.32	.0411
17	34.61	219.6	1148.3	22.96	.0435
18	36.65	222.4	1149.2	21.78	.0459
19	38.68	225.3	1150.1	20.7	.0483
20	40.72	228.	1150.9	19.72	.0507
21	42.75	230.6	1151.7	18.84	.0531
22	44.79	233.1	1152.5	18.03	.0555
23	46.83	235.5	1153.2	17.26	.058
24	48.86	237.8	1153.9	16.64	.0601
25	50.9	240.1	1154.6	15.99	.0625
26	52.93	242.3	1155.3	15.38	.065
27	54.97	244.4	1155.8	14.86	.0673
28	57.01	246.4	1156.4	14.37	.0696
29	59.04	248.4	1157.1	13.9	.0719

Properties of Saturated Steam (*Continued*).

Pressure per sq. in.	Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.	Volume of 1 Pound.	Density or Wt. of 1 Cubic Foot.
Lbs.	Ins.	Deg.	Deg.	Cu. Ft.	Lb.
30	61.08	250.4	1157.8	13.46.	.0743
31	63.11	252.2	1158.4	13.05	.0766
32	65.15	254.1	1158.9	12.67	.0789
33	67.19	255.9	1159.5	12.31	.0812
34	69.22	257.6	1160.	11.97	.0835
35	71.26	259.3	1160.5	11.65	.0858
36	73.29	260.9	1161.	11.34	.0881
37	75.33	262.6	1161.5	11.04	.0905
38	77.37	264.2	1162.	10.76	.0929
39	79.4	265.8	1162.5	10.51	.0952
40	81.43	267.3	1162.9	10.27	.0974
41	83.47	268.7	1163.4	10.03	.0996
42	85.5	270.2	1163.8	9.81	.102
43	87.54	271.6	1164.2	9.59	.1042
44	89.58	273.	1164.6	9.39	.1065
45	91.61	274.4	1165.1	9.18	.1089
46	93.65	275.8	1165.5	9.	.1111
47	95.69	277.1	1165.9	8.82	.1133
48	97.72	278.4	1166.3	8.65	.1156
49	99.76	279.7	1166.7	8.48	.1179
50	101.8	281.	1167.1	8.31	.1202
51	103.83	282.3	1167.5	8.17	.1224
52	105.87	283.5	1167.9	8.04	.1246
53	107.9	284.7	1168.3	7.88	.1269
54	109.94	285.9	1168.6	7.74	.1291
55	111.98	287.1	1169.	7.61	.1314
56	114.01	288.2	1169.3	7.48	.1336
57	116.05	289.3	1169.7	7.36	.1364
58	118.08	290.4	1170.	7.24	.138
59	120.12	291.6	1170.4	7.12	.1403
60	122.16	292.7	1170.7	7.01	.1425
61	124.19	293.8	1171.1	6.9	.1447
62	126.23	294.8	1171.4	6.81	.1469
63	128.26	295.9	1171.7	6.7	.1493
64	130.3	296.9	1172.	6.6	.1516
65	132.34	298.	1172.3	6.49	.1538
66	134.37	299.	1172.6	6.41	.156
67	136.4	300.	1172.9	6.32	.1583
68	138.44	300.9	1173.2	6.23	.1605
69	140.48	301.9	1173.5	6.15	.1627

Properties of Saturated Steam (*Concluded*).

Pressure per sq. in.	Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.	Volume of 1 Pound.	Density or Wt. of 1 Cubic Foot.
Lbs.	Ins.	Deg.	Deg.	Cu. Ft.	Lb.
150	305.39	358.3	1190.7	2.96	.3377
155	315.57	361.	1191.5	2.87	.3484
160	325.75	363.4	1192.2	2.79	.359
165	335.93	366.	1192.9	2.71	.3695
170	346.11	368.2	1193.7	2.63	.3798
175	356.29	370.8	1194.4	2.56	.3899
180	366.47	372.9	1195.1	2.49	.4009
185	376.65	375.3	1195.8	2.43	.4117
190	386.83	377.5	1196.5	2.37	.4222
195	397.01	379.7	1197.2	2.31	.4327
200	407.19	381.7	1197.8	2.26	.4431
210	427.54	386.	1199.1	2.16	.4634
220	447.9	389.9	1200.3	2.06	.4842
230	468.26	393.8	1201.5	1.98	.5052
240	488.62	397.5	1202.6	1.9	.5248
250	508.98	401.1	1203.7	1.83	.5464
260	529.34	404.5	1204.8	1.76	.5669
270	549.7	407.9	1205.8	1.7	.5868
280	570.06	411.2	1206.8	1.64	.6081
290	590.42	414.4	1207.8	1.59	.6273
300	610.78	417.5	1208.7	1.54	.6486
350	712.57	430.1	1212.6	1.33	.7498
400	814.37	444.9	1217.1	1.18	.8502
450	916.17	456.7	1220.7	1.05	.9499
500	1018.	467.5	1224.	.95	1.049
550	1119.8	477.5	1227.	.87	1.148
600	1221.6	487.	1229.9	.8	1.245
650	1323.4	495.6	1232.5	.74	1.342
700	1425.8	504.1	1235.1	.69	1.4395
800	1628.7	519.5	1239.8	.61	1.6322
900	1832.3	533.6	1244.2	.55	1.8235
1000	2035.9	546.5	1248.1	.5	2.014

Table No. 7.

Tensile Strength of Bolts.

Diameter of Bolt in Inches.	Area at Bottom of Thread.	At 7,000 lbs. per Sq. Inch.	At 10,000 lbs. per Sq. Inch.	At 12,000 lbs. per Sq. Inch.	At 15,000 lbs. per Sq. Inch.	At 20,000 lbs. per Sq. Inch.
$\frac{1}{2}$	.125	875	1250	1500	1875	2500
$\frac{5}{8}$	.196	1372	1960	2350	2940	3920
$\frac{3}{4}$	.3	2100	3000	3600	4500	6000
$\frac{7}{8}$	.42	2940	4200	5040	6300	8400
1	.55	3850	5500	6600	8250	11000
$1\frac{1}{8}$	.69	4830	6900	8280	10350	13800
$1\frac{1}{4}$	.89	5460	7800	9360	11700	15600
$1\frac{3}{8}$	1.06	7420	10600	12720	15900	21200
$1\frac{1}{2}$	1.28	8960	12800	15360	19200	25600
$1\frac{5}{8}$	1.53	10710	15300	18360	22950	30600
$1\frac{3}{4}$	1.76	12320	17600	21120	26400	35200
$1\frac{7}{8}$	2.03	14210	20300	24360	30450	40600
2	2.3	16100	23000	27600	34500	46000
$2\frac{1}{4}$	3.12	21840	31200	37440	46800	62400
$2\frac{1}{2}$	3.7	25900	37000	44400	55500	74000
$2\frac{3}{4}$	4.6	32200	46000	55200	69000	92000
3	5.44	38080	54400	65280	81600	108800
$3\frac{1}{4}$	6.6	46200	66000	79200	99000	132000
$3\frac{1}{2}$	7.54	52780	75400	90480	113100	150800
$3\frac{3}{4}$	8.6	60200	86000	103200	129000	172000
4	9.9	69300	99000	118800	148500	198000
$4\frac{1}{4}$	11.3	79100	113000	135600	169500	226000
$4\frac{1}{2}$	12.68	88760	126800	152000	190200	253600
$4\frac{3}{4}$	14.186	99300	141860	170220	212790	283720
5	15.76	110300	157600	189120	236400	315200
$5\frac{1}{4}$	17.57	122990	175700	210840	263550	351400
$5\frac{1}{2}$	19.24	134680	192400	230880	288600	384800
$5\frac{3}{4}$	21.237	148660	212370	254840	318555	424740
6	23.07	161490	230700	276840	346050	461400

Table No. 8.

Breaking Strength of Bolts.

$\frac{3}{8}$ in.	$\frac{7}{16}$ in.	$\frac{1}{2}$ in.	$\frac{9}{16}$ in.	$\frac{5}{8}$ in.	$\frac{11}{16}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
4,575 Lbs.	4,950 Lbs.	7,700 Lbs.	9,000 Lbs.	11,225 Lbs.	15,000 Lbs.	18,200 Lbs.	23,500 Lbs.	30,000 Lbs.
$1\frac{1}{8}$ in.	$1\frac{1}{4}$ in.	$1\frac{1}{2}$ in.	$1\frac{3}{4}$ in.	2 in.	$2\frac{1}{4}$ in.	$2\frac{1}{2}$ in.	$2\frac{3}{4}$ in.	3 in.
35,500 Lbs.	41,000 Lbs.	63,000 Lbs.	88,000 Lbs.	120,000 Lbs.	145,000 Lbs.	180,000 Lbs.	220,000 Lbs.	275,000 Lbs.

TABLE No. 9.

Maximum Bending Moments on Pins with Extreme End Fibre Stresses.

Varying from 15,000 to 25,000 Pounds per Square Inch.

Diameter of Pin in Inches.	Area of Pin in Square Inches.	MOMENTS IN INCH-POUNDS FOR FIBRE STRESSES OF				
		15,000 Lbs. per Sq. In.	18,000 Lbs. per Sq. In.	20,000 Lbs. per Sq. In.	22,500 Lbs. per Sq. In.	25,000 Lbs. per Sq. In.
1	.785	1470	1770	1960	2210	2450
1⅛	.994	2100	2520	2800	3150	3490
1¼	1.227	2900	3450	3830	4310	4790
1⅜	1.485	3830	4590	5100	5740	6380
1½	1.767	4970	5960	6630	7460	8280
1⅝	2.074	6320	7580	8430	9480	10530
1¾	2.405	7890	9470	10520	11840	13150
1⅞	2.761	9710	11650	12940	14560	16180
2	3.142	11780	14140	15710	17670	19630
2⅛	3.547	14130	16960	18840	21200	23550
2¼	3.976	16770	20130	22370	25160	27960
2⅜	4.430	19730	23670	26300	29590	32880
2½	4.909	23010	27610	30680	34510	38350
2⅝	5.412	26640	31960	35520	39960	44400
2¾	5.940	30630	36750	40830	45940	51040
2⅞	6.492	34990	41990	46660	52490	58320
3	7.069	39730	47680	52970	59600	66220
3⅛	7.670	44940	53930	59920	67410	74900
3¼	8.296	50550	60660	67400	75830	84250
3⅜	8.946	56610	67940	75480	84920	94350
3½	9.621	63140	75770	84180	94710	105230
3⅝	10.321	70150	84180	93530	105220	116910
3¾	11.045	77660	93190	103540	116490	129430
3⅞	11.793	85690	102820	114250	128530	142810
4	12.566	94250	113100	125660	141370	157080
4⅛	13.364	103360	124040	137820	155040	172270
4¼	14.186	113050	135660	150730	169570	188410
4⅜	15.033	123320	147980	164420	184980	205530
4½	15.904	134190	161030	178920	201290	223650
4⅝	16.800	145690	174830	194250	218510	242810
4¾	17.721	157820	189390	210430	236740	263040
4⅞	18.665	170580	204740	227490	255920	284360

Maximum Bending Moments on Pins with Extra Fibre Stresses.

Varying from 15,000 to 25,000 Pounds per Square Inch (*Concluded*).

Diameter of Pin in Inches.	Area of Pin in Square Inches.	Moments in Inch-Pounds for Fibre Stresses of				
		15,000 Lbs. per Sq. In.	18,000 Lbs. per Sq. In.	20,000 Lbs. per Sq. In.	22,500 Lbs. per Sq. In.	25,000 Lbs. per Sq. In.
5	19.635	184080	220890	245440	276120	306800
5⅛	20.629	198230	237880	264310	297350	330390
5¼	21.648	213090	255710	284120	319640	355160
5⅜	22.691	228680	274420	304910	343020	381130
5½	23.758	245010	294010	326680	367510	408350
5⅝	24.850	262100	314510	349460	393140	436830
5¾	25.967	279960	335950	373280	419940	466600
5⅞	27.109	298620	358340	398160	447930	497700

Table No. 10.

BEARING VALUES OF PIN PLATES.

For One Inch Thickness of Plate.

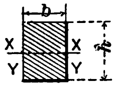
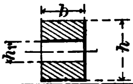
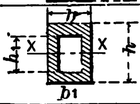
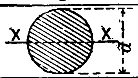
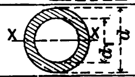
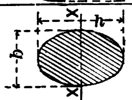
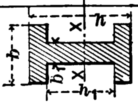
Bearing value = Diameter of Pin × 1″ × Stress Per Square Inch.

Diameter of Pin.	Area of Pin.	Bearing Value at 12,000 Pounds per Square Inch.	Bearing Value at 13,500 Pounds per Square Inch.	Bearing Value at 15,000 Pounds per Square Inch.	Diameter of Pin.	Area of Pin.	Bearing Value at 12,000 Pounds per Square Inch.	Bearing Value at 13,5000 Pounds per Square Inch.	Bearing Value at 15,000 Pounds per Square Inch.
Inch	Sq. In.	Pounds	Pounds	Pounds	Inches.	Sq. In.	Pounds	Pounds	Pounds
1	.785	12000	13500	15000	4 1/2	15.90	54000	60750	67500
1 1/8	.994	13500	15190	16880	4 5/8	16.80	55500	62440	69380
1 1/4	1.227	15000	16880	18750	4 3/4	17.72	57000	64130	71250
1 3/8	1.485	16500	18560	20630	4 7/8	18.67	58500	65810	73130
1 1/2	1.767	18000	20250	22500	5	19.64	60000	67500	75000
1 5/8	2.074	19500	21940	24380	5 1/8	20.63	61500	69190	76880
1 3/4	2.405	21000	23630	26250	5 1/4	21.65	63000	70880	78750
1 7/8	2.761	22500	25310	28130	5 3/8	22.69	64500	72560	80630
2	3.142	24000	27000	30000	5 1/2	23.76	66000	74250	82500
2 1/8	3.547	25500	28690	31880	5 5/8	24.85	67500	75940	84380
2 1/4	3.976	27000	30380	33750	5 3/4	25.97	69000	77630	86250
2 3/8	4.430	28500	32060	35630	5 7/8	27.11	70500	79310	88130
2 1/2	4.909	30000	33750	37500	6	28.27	72000	81000	90000
2 5/8	5.412	31500	35440	39380	6 1/8	29.46	73500	82690	91880
2 3/4	5.940	33000	37130	41250	6 1/4	30.68	75000	84380	93750
2 7/8	6.492	34500	38810	43130	6 3/8	31.92	76500	86060	95630
3	7.069	36000	40500	45000	6 1/2	33.18	78000	87750	97500
3 1/8	7.670	37500	42190	46880	6 5/8	34.47	79500	89440	99380
3 1/4	8.296	39000	43880	48750	6 3/4	35.79	81000	91130	101250
3 3/8	8.946	40500	45560	50630	6 7/8	37.12	82500	92810	103130
3 1/2	9.621	42000	47250	52500	7	38.48	84000	94500	105000
3 5/8	10.32	43500	48940	54380	7 1/2	44.18	90000	101250	112500
3 3/4	11.05	45000	50630	56250	8	50.27	96000	108000	120000
3 7/8	11.79	46500	52310	58130	8 1/2	56.75	102000	114750	127500
4	12.57	48000	54000	60000	9	63.62	108000	121500	135000
4 1/8	13.36	49500	55690	61880	10	78.54	120000	135000	150000
4 1/4	14.19	51000	57380	63750	11	95.03	132000	148500	165000
4 3/8	15.03	52500	59060	65630	12	113.10	144000	162000	180000

Table No. 11.

Values of Moments of Inertia.

I=Moment of Inertia. Z=Moment of Resistance.

Sections	I	Z
	For axis X–X$=\dfrac{b\,h^3}{12}$ For axis Y–Y$=\dfrac{b\,h^3}{3}$	$\dfrac{b\,h^2}{6}$
	$\dfrac{b\,(h^3-h_1^3)}{12}$	$\dfrac{b\,(h^3-h_1^3)}{6\,h}$
	$\dfrac{b\,h^3-b_1 h_1^3}{12}$	$\dfrac{b\,h^3-b_1\,h_1^3}{6\,h}$
	$\dfrac{\pi d^4}{64}$	$\dfrac{\pi\,d^3}{32}$
	$\dfrac{\pi\,(d^4-d_1^4)}{64}$	$\dfrac{\pi\,(d^4-d_1^4)}{32\,d}$
	$\dfrac{\pi\,b\,h^3}{64}$	$\dfrac{\pi\,b\,h^2}{32}$
	$\dfrac{b\,h^3-(b-b_1)h_1^3}{12}$	$\dfrac{2\,I}{h}$

The Derry Collard Co.

Table No. 12.

Deflection and Maximum Bending Moment of Beams Under Varying Conditions of Load.

Beam.	Condition of Load.	Maximum Bending Moment.	Maximum Deflection.
Cantilever.	Load at end.	WL	$\frac{WL^3}{3\,EI}$
Cantilever.	Uniformly loaded.	$\frac{WL}{2}$	$\frac{WL^3}{8\,EI}$
Simple.	Loaded in center.	$\frac{WL}{4}$	$\frac{WL^3}{48\,EI}$
Simple.	Uniformly loaded.	$\frac{WL}{8}$	$\frac{5\,WL^3}{384\,EI}$
One end fixed, other end supported.	Loaded in center.	$.192\,WL$	$.0182\,\frac{WL^3}{EI}$
One end fixed, other end supported.	Uniformly loaded.	$\frac{WL}{8}$	$.0054\,\frac{WL^3}{EI}$
Beam fixed at both ends.	Loaded in center.	$\frac{WL}{8}$	$\frac{WL^3}{192\,EI}$
Beam fixed at both ends.	Uniformly loaded.	$\frac{WL}{12}$	$\frac{WL^3}{384\,EI}$

Table No. 13.

Table Showing Thickness of Shell and Safe Working Pressure for Horizontal Tubular Steel Boilers.

(Bair.)

Diameter of Shell, Inches.	Thickness of Shell, Inches.	Longitudinal Seams. Single Riveted.			Longitudinal Seams Double Staggered Riveted.			Longitudinal Seams Double Triple Riveted Butt Joint		
		Tensile Strength of Steel.			Tensile Str'ngth of Steel			Tensile Str'ngth of Steel		
		50000 Pounds	55000 Pounds	60000 Pounds	50000 Pounds	55000 Pounds	60000 Pounds	50000 Pounds	55000 Pounds	60000 Pounds
		Pressure Pounds	Pressure Pounds	Pressure Pounds	Pr'ss're Pounds	Pr'ss're Pounds	Pr'ss're Pounds	Pr'ss're Pounds	Pr'ss're Pounds	Pr'ss're Pounds
24	$\frac{1}{4}$	118	130	142	150	165	180	...	...	...
	$\frac{5}{16}$	148	163	178	187	206	225	...	...	...
28	$\frac{1}{4}$	101	112	122	128	141	154	...	...	...
	$\frac{5}{16}$	127	139	152	156	171	187	...	...	...
30	$\frac{1}{4}$	95	104	114	116	128	140	...	...	...
	$\frac{5}{16}$	118	130	142	145	160	175	...	...	...
34	$\frac{1}{4}$	83	92	100	102	113	123	...	...	...
	$\frac{5}{15}$	104	115	125	128	141	154	...	...	...
36	$\frac{1}{4}$	79	87	95	97	106	116	...	...	...
	$\frac{5}{15}$	98	108	118	121	133	145	...	...	...
38	$\frac{1}{4}$	75	82	90	92	101	110	...	...	...
	$\frac{5}{15}$	93	103	112	115	126	138	...	...	...
40	$\frac{9}{32}$	80	88	96	98	108	118	...	...	...
	$\frac{5}{16}$	89	97	106	109	120	131	...	...	...
42	$\frac{9}{32}$	76	84	91	93	103	112	...	...	...
	$\frac{5}{16}$	85	92	101	104	114	125	...	...	...
44	$\frac{3}{10}$	77	85	93	95	105	114	...	...	...
	$\frac{32}{100}$	82	91	98	101	112	122	...	...	...
46	$\frac{5}{16}$	77	85	92	95	104	114	...	...	...
	$\frac{34}{100}$	84	92	101	103	113	124	...	...	...
48	$\frac{32}{100}$	76	83	91	93	102	112	114	126	137
	$\frac{36}{100}$	85	94	102	105	115	126	129	141	154
50	$\frac{33}{100}$	75	82	90	92	101	110	113	124	136
	$\frac{36}{100}$	82	90	98	100	110	120	123	136	148
52	$\frac{34}{100}$	74	81	89	91	100	109	112	123	134
	$\frac{36}{100}$	78	86	94	96	106	116	119	130	142
54	$\frac{36}{100}$	76	83	91	93	102	112	114	126	137
	$\frac{3}{8}$	79	87	95	97	106	116	119	131	143
56	$\frac{3}{8}$	76	83	91	93	103	112	115	126	138
	$\frac{4}{10}$	81	89	97	100	110	120	122	135	147
60	$\frac{4}{10}$	76	83	91	93	102	112	114	126	137
	$\frac{42}{100}$	79	87	95	98	107	117	120	132	144
66	$\frac{43}{100}$	74	81	89	91	100	109	112	123	134
	$\frac{45}{100}$	77	85	93	95	105	114	117	129	140
72	$\frac{45}{100}$	71	78	85	84	96	105	107	118	129
	$\frac{48}{100}$	76	83	91	93	102	112	114	122	137
78	$\frac{45}{100}$	65	72	78	80	88	96	99	109	119
	$\frac{1}{2}$	73	80	87	89	98	107	110	121	132
84	$\frac{45}{100}$	61	67	73	75	82	90	92	101	109
	$\frac{1}{2}$	67	77	81	83	91	100	102	112	122

In above table a factor of safety of 5 was used.

Table No. 14.

Table Showing Working Pressure and Thickness of Morison Corrugated Furnaces.

Inside Diameter.	Working Pressure in Pounds per Square Inch. — Thickness of Furnace.														
	5/16 in.	11/32 in.	3/8 in.	13/32 in.	7/16 in.	15/32 in.	1/2 in.	17/32 in.	9/16 in.	19/32 in.	5/8 in.	21/32 in.	11/16 in.	23/32 in.	3/4 in.
28 Inches	156	172	188	203	219	234	250	264	280	295	310	326	341	356	371
29 "	151	166	181	196	211	226	241	256	271	285	300	315	330	344	360
30 "	146	161	176	190	205	219	234	248	263	276	291	305	320	333	348
31 "	142	156	171	184	199	212	227	241	254	268	282	296	310	323	338
32 "	138	152	166	179	192	206	220	234	247	260	274	287	301	315	327
33 "	134	147	161	174	187	200	214	227	240	253	266	279	292	305	318
34 "	130	143	156	169	182	195	208	220	234	246	259	271	284	297	309
35 "	127	140	152	164	177	189	202	215	227	239	252	264	277	289	301
36 "	123	136	148	160	172	184	197	209	221	233	245	257	269	281	294
37 "	120	132	144	156	168	179	192	203	216	227	239	251	262	274	286
38 "	117	129	141	152	164	175	187	198	209	221	233	244	256	267	279
39 "	114	126	137	148	160	171	182	193	205	215	227	238	250	260	272
40 "	111	123	134	144	156	167	178	189	200	211	222	232	244	254	266
41 "	109	120	130	141	152	163	174	184	195	206	216	227	238	249	259
42 "	106	117	127	138	149	159	170	180	191	201	211	222	233	243	253
43 "	104	114	125	135	145	155	166	176	186	196	207	217	227	237	248
44 "	102	112	122	132	142	152	163	172	182	192	203	212	222	232	243
45 "	99	110	120	129	139	149	159	168	178	188	198	208	218	227	237
46 "	97	107	117	127	136	146	156	165	175	184	194	204	213	223	232
47 "	95	105	114	124	133	143	153	161	171	180	190	200	209	218	228
48 "	93	103	112	121	131	140	150	158	167	177	186	196	204	213	223
49 "	92	101	110	119	128	137	147	155	164	173	183	192	201	209	219
50 "	90	99	108	116	126	134	144	152	162	170	179	188	197	206	215
51 "	88	97	106	114	123	132	141	150	158	167	176	185	193	201	210
52 "	86	95	104	112	121	129	138	147	155	164	173	181	189	198	207
53 "	85	93	102	110	119	127	136	144	153	161	170	177	186	194	203
54 "	83	92	100	108	117	125	133	141	150	158	166	175	183	190	199
55 "	82	90	98	107	115	123	131	139	147	155	163	171	180	188	196
56 "	80	89	97	105	112	120	129	136	145	152	161	168	176	184	192
57 "	79	87	95	103	111	118	127	134	142	150	158	165	173	181	189
58 "	78	86	93	101	110	117	125	132	140	147	155	163	171	178	186
59 "	76	84	92	99	107	115	122	130	137	145	153	160	168	175	183
60 "	75	83	90	98	105	113	120	127	135	142	150	158	165	173	180

TABLE No. 14 (*Concluded*).

Rules for Calculating Thickness and the Pressure Allowance on Morison Suspension Furnaces.

As adopted by the board of U. S. Supervising Inspectors of Steam Vessels. Corrugations to be 8 inches pitch and 1½ inches deep, the plain parts at ends not to exceed 6 inches:

$$T = \frac{P \times D}{15{,}000}$$

T = Thickness of furnace in inches.
P = Working pressure in pounds per square inch.
D = Mean diameter of furnace in inches = inside diameter + thickness of metal + 1½ in.
15,000 = a Constant.

EXAMPLE: Given, a furnace 40 inches mean diameter, to carry a steam pressure of 187 pounds. Required; the thickness of metal necessary.

$$T = \frac{187 \times 40}{15{,}000} = \tfrac{1}{2} \text{ inch.}$$

EXAMPLE: Given, a furnace 40 inches mean diameter, ½ inch thick. Required; the steam pressure allowable. By transposing the above rule, we have

$$P = \frac{15{,}000}{D} \times T \qquad \text{Hence, } P = \frac{15{,}000}{40} \times \tfrac{1}{2} = 187 \text{ pounds.}$$

Table No. 15.

Fire Box Steel Specifications of Leading Railroads, Associations and Locomotive Works.

NAME.	Minimum Tensile Strength.	Maximum Tensile Strength.	Minimum Elonga-tion.	Maximum Carbon.	Minimum Carbon.	Maximum Phosphor-us.	Maximum Sulphur.	Maximum Mangan-ese.	Maximum Silicon.	Maximum Copper.
Pennsylvania R. R. Co.	55000	65000	25% in 8″	.25	.15	.035	.045	.45	.03	.05
Philadelphia & Reading R. R.	52000	60000	30% in 2″	...	...	.035	.04	...	...	...
Baltimore & Ohio R. R.	55000	65000	....	.25	.15	.035	.035	.45	.03	.05
Seaboard Air Line	55000	60000	22% in 8″	.25	.15	.035	.035	.45	.03	...
South Carolina & Georgia R. R.	55000	65000	22% in 8″	.25	.15	.035	.045	.45	.03	...
Canada Pacific R. R.	50000	58000	25% in 8″	...	...	...	...	...	...	...
Chicago & Northwestern R. R.	50000	65000	25% in 8″	...	...	...	...	...	...	...
Chicago, Milw. & St. Paul R. R.	50000	60000	25% in 5″	...	...	...	...	...	...	...
Chicago, Burl'g'n & Quincy R. R.	50000	60000	25% in 4″	...	...	...	...	...	...	...
Great Northern R'y.	52000	60000	25% in 8″	.20	.13	.03	.03	.40	.02	.03
Northern Pacific R'y.	54000	62000	25%	.20	.12	.03	.02	.40	.02	...
Union Pacific R'y.	50000	56000	28% in 4″	.20	...	.04	.04	.50	.04	.04
Missouri Pacific R'y.	48000	55000	28% in 8″	...	...	...	...	...	...	...
Southern Pacific R'y.	50000	65000	25% in 4″	...	...	...	...	...	...	...
Baldwin Locomotive Works.	55000	65000	25% in 8″	.25	.15	.03	.035	.45	.03	...
Cooke Locomotive Works.	52000	62000	26%	...	...	.04	.04	...	...	...
Railway Master Mechanic's Ass'n	55000	65000	25% in 8″	.25	.15	.035	.035	.45	.03	...

In addition to above tests, the Railway Master Mechanics' Association and some of the principal railroads require a test for homogeneity by nicking a test piece on alternate sides in three places and breaking where nicked; a cavity more than ¼ inch long in any of the three fractures being sufficient cause for rejection of the plate.

Table No. 16.

Decimals of an Inch for Each 1-64th.

1/32ds	1/64 ths	Decimal	Fraction	1/32 ds	1/64 ths	Decimal	Fraction
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	1/16	18	36	.5625	9/16
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	1/8	20	40	.625	5/8
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	3/16	22	44	.6875	11/16
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	1/4	24	48	.75	3/4
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	5/16	26	52	.8125	13/16
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	3/8	28	56	.875	7/8
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	7/16	30	60	.9375	15/16
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	1/2	32	64	1.	1

Table No. 17.

Decimal Fractions of a Square Foot in Square Inches.

Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.
0.01	1.44	0.26	37.4	0.51	73.4	0.76	109.4
0.02	2.88	0.27	38.9	0.52	74.9	0.77	110.9
0.03	4.32	0.28	40.3	0.53	76.3	0.78	112.3
0.04	5.76	0.29	41.8	0.54	77.8	0.79	113.8
0.05	7.20	0.30	43.2	0.55	79.2	0.80	115.2
0.06	8.64	0.31	44.6	0.56	.80.6	0.81	116.6
0.07	10.1	0.32	46.1	0.57	82.1	0.82	118.1
0.08	11.5	0.33	47.5	0.58	83.5	0.83	119.5
0.09	13.0	0.34	49.0	0.59	85.0	0.84	121.0
0.10	14.4	0.35	50.4	0.60	86.4	0.85	122.4
0.11	15.8	0.36	51.8	0.61	87.8	0.86	123.8
0.12	17.3	0.37	53.3	0.62	89.3	0.87	125.3
0.13	18.7	0.38	54.7	0.63	90.7	0.88	126.7
0.14	20.2	0.39	56.2	0.64	92.2	0.89	128.2
0.15	21.6	0.40	57.6	0.65	93.6	0.90	129.6
0.16	23.0	0.41	58.0	0.66	95.0	0.91	131.0
0.17	24.5	0.42	60.5	0.67	96.5	0.92	132.5
0.18	25.9	0.43	61.9	0.68	97.9	0.93	133.9
0.19	27.4	0.44	63.4	0.69	99.4	0.94	135.4
0.20	28.8	0.45	64.8	0.70	100.8	0.95	136.8
0.21	30.2	0.46	66.2	0.71	102.2	0.96	138.2
0.22	31.7	0.47	67.7	0.72	103.7	0.97	139.7
0.23	33.1	0.48	69.1	0.73	105.1	0.98	141.1
0.24	34.6	0.49	70.6	0.74	106 6	0.99	142.6
0.25	36.0	0.50	72.0	0.75	108.0	1 00	144.0

TABLE No. 18.

Square Inches in Decimal Fractions of a Square Foot.

Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.
0.10	0.0006944	24.0	0.16666	65.0	0.45138	105.0	0.72916
0.15	0.0010416	25.0	0.17361	66.0	0.45833	106.0	0.73611
0.20	0.001388	26.0	0.18055	67.0	0.46527	107.0	0.74305
0.25	0.0017361	27.0	0.18750	68.0	0.47222	108.0	0.75000
0.30	0.002083	28.0	0.19444	69.0	0.47916	109.0	0.75694
0.35	0.0024305	29.0	0.20138	70.0	0.48611	110.0	0.76388
0.40	0.002777	30.0	0.20833	71.0	0.49305	111.0	0.77083
0.45	0.00311249	31.0	0.21527	72.0	0.50000	112.0	0.77777
0.50	0.003472	32.0	0.22222	73.0	0.50694	113.0	0.78472
0.55	0.0038194	33.0	0.22916	74.0	0.51388	114.0	0.79166
0.60	0.004166	34.0	0.23611	75.0	0.52083	115.0	0.79861
0.65	0.0045138	35.0	0.24305	76.0	0.52777	116.0	0.80555
0.70	0.004861	36.0	0.25000	77.0	0.53472	117.0	0.81249
0.75	0.0052083	37.0	0.25694	78.0	0.54166	118.0	0.81944
0.80	0.005555	38.0	0.26388	79.0	0.54861	119.0	0.82638
0.85	0.0059027	39.0	0.27083	80.0	0.55555	120.0	0.83333
0.90	0.006250	40.0	0.27777	81.0	0.56249	121.0	0.84027
0.95	0.0065972	41.0	0.28472	82.0	0.56944	122.0	0.84722
1.0	0.006944	42.0	0.29166	83.0	0.57638	123.0	0.85416
2.0	0.01388	43.0	0.29861	84.0	0.58333	124.0	0.86111
3.0	0.02083	44.0	0.30555	85.0	0.59027	125.0	0.86805
4.0	0.02777	45.0	0.31249	86.0	0.59722	126.0	0.87500
5.0	0.03472	46.0	0.31944	87.0	0.60416	127.0	0.88194
6.0	0.04166	47.0	0.32638	88.0	0.61111	128.0	0.88888
7.0	0.04861	48.0	0.33333	89.0	0.61805	129.0	0.89583
8.0	0.05555	49.0	0.34027	90.0	0.62500	130.0	0.90277
9.0	0.06250	50.0	0.34722	91.0	0.63194	131.0	0.90972
10.0	0.06944	51.0	0.35416	92.0	0.63888	132.0	0.91666
11.0	0.07638	52.0	0.36111	93.0	0.64583	133.0	0.92361
12.0	0.08333	53.0	0.36805	94.0	0.65277	134.0	0.93055
13.0	0.09027	54.0	0.37500	95.0	0.65972	135.0	0.93750
14.0	0.09722	55.0	0.38194	96.0	0.66666	136.0	0.94444
15.0	0.10416	56.0	0.38888	97.0	0.67361	137.0	0.95138
16.0	0.11111	57.0	0.39583	98.0	0.68055	138.0	0.95833
17.0	0.11805	58.0	0.40277	99.0	0.68750	139.0	0.96527
18.0	0.12500	59.0	0.40972	100.0	0.69444	140.0	0.97222
19.0	0.13194	60.0	0.41666	101.0	0.70138	141.0	0.97916
20.0	0.13888	61.0	0.42361	102.0	0.70833	142.0	0.98611
21.0	0.14583	62.0	0.43055	103.0	0.71527	143.0	0.99305
22.0	0.15277	63.0	0.43750	104.0	0.72222	144.0	1.0000
23.0	0.15972	64.0	0.44444				

TABLE No. 19.

Lineal Inches in Decimal Fractions of a Lineal Foot.

Lineal Inches.	Lineal Foot.	Lineal Inches.	Lineal Foot.	Lineal Inches.	Lineal Foot
1/64	0.001302083	1 7/8	0.15625	6 1/2	0.5416
1/32	0.00260416	2	0.1666	6 3/4	0.5625
1/16	0.0052083	2 1/8	0.177083	7	0.5833
1/8	0.010416	2 1/4	0.1875	7 1/4	0.60416
3/16	0.015625	2 3/8	0.197916	7 1/2	0.625
1/4	0.02083	2 1/2	0.2083	7 3/4	0.64583
5/16	0.0260416	2 5/8	0.21875	8	0.66667
3/8	0.03125	2 3/4	0.22916	8 1/4	0.6875
7/16	0.0364583	2 7/8	0.239583	8 1/2	0.7083
1/2	0.0416	3	0.25	8 3/4	0.72916
9/16	0.046875	3 1/4	0.27083	9	0.75
5/8	0.052083	3 1/2	0.2916	9 1/4	0.77083
11/16	0.0572916	3 3/4	0.3125	9 1/2	0.7916
3/4	0.0625	4	0.33333	9 3/4	0.8125
13/16	0.0677083	4 1/4	0.35416	10	0.83333
7/8	0.072916	4 1/2	0.375	10 1/4	0.85416
15/16	0.078125	4 3/4	0.39583	10 1/2	0.875
1	0.0833	5	0.4166	10 3/4	0.89583
1 1/8	0.09375	5 1/4	0.4375	11	0.9166
1 1/4	0.10416	5 1/2	0.4583	11 1/4	0.9375
1 3/8	0.114583	5 3/4	0.47916	11 1/2	0.9583
1 1/2	0.125	6	0.5	11 3/4	0.97916
1 5/8	0.135416	6 1/4	0.52083	12	1.000
1 3/4	0.14583				

TABLE No. 20.

Coefficients of Linear Expansion at Temperatures Between 32° Fahr. and 212° Fahr.

Material.	For 1° Cent.	For 1° Fahr.
Aluminium, cast	.0000222	.0000123
Aluminium, rolled	.0000207	.0000115
Brass	.0000189	.0000105
Iron, cast	.0000108	.0000060
Iron, wrought	.0000117	.0000065
Steel, untempered	.0000108	.0000060
Steel, tempered	.0000126	.0000070
Fire brick	.0000049	.0000027
Glass	.0000088	.0000049

Table No. 21.

Proportions for U. S. Standard.

SCREW THREADS AND NUTS.

Diameter of Screw.	Threads per Inch.	Diameter at Root of Thread.	Short Diameter of Nuts.	Long Diameter, Hexagon Nuts.	Long Diameter, Square Nuts.	Thickness of Nuts.
1/4	20	.185	1/2	37/64	7/10	1/4
5/16	18	.240	19/32	11/16	10/12	5/16
3/8	16	.294	11/16	51/64	62/64	3/8
7/16	14	.344	25/32	9/10	1 7/64	7/16
1/2	13	.400	7/8	1	1 15/64	1/2
9/16	12	.454	31/32	1 1/8	1 23/64	9/16
5/8	11	.507	1 1/16	1 7/32	1 1/2	5/8
3/4	10	.620	1 1/4	1 7/16	1 49/64	3/4
7/8	9	.731	1 7/16	1 21/32	2 1/32	7/8
1	8	.837	1 5/8	1 7/8	2 19/64	1
1 1/8	7	.940	1 13/16	2 3/32	2 9/16	1 1/8
1 1/4	7	1.065	2	2 5/16	2 53/64	1 1/4
1 3/8	6	1.160	2 3/16	2 17/32	3 3/32	1 3/8
1 1/2	6	1.284	2 3/8	2 3/4	3 23/64	1 1/2
1 5/8	5 1/2	1.389	2 9/16	2 31/32	3 5/8	1 5/8
1 3/4	5	1.491	2 3/4	3 3/16	3 57/64	1 3/4
1 7/8	5	1.616	2 15/16	3 13/32	4 5/32	1 7/8
2	4 1/2	1.712	3 1/8	3 5/8	4 27/64	2
2 1/4	4 1/2	1.962	3 1/2	4 1/16	4 61/64	2 1/4
2 1/2	4	2.176	3 7/8	4 1/2	5 31/64	2 1/2
2 3/4	4	2.426	4 1/4	4 29/32	6	2 3/4
3	3 1/2	2.629	4 5/8	5 3/8	6 17/32	3
3 1/4	3 1/2	2.879	5	5 13/16	7 1/16	3 1/4
3 1/2	3 1/4	3.100	5 3/8	6 7/64	7 39/64	3 1/2
3 3/4	3	3.317	5 3/4	6 21/32	8 1/8	3 3/4
4	3	3.567	6 1/8	7 3/32	8 41/64	4

Table No. 22.

Lap-Welded Locomotive Boiler Tubes

Table of Standard Dimensions.

Diameter.		Thickness.	Wire Gage.	Circumference.		Transverse Areas.			Length of Tube per Sq. Foot of		Nominal Weight per Foot.
Ext'rnal	Internal.			External.	Internal.	External.	Internal.	Metal.	External Surface.	Internal Surface.	
Inch'	Inches.	Inches.	No.	Inches.	Inches.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet.	Feet.	Pounds.
1	.834	.083	14	3.1416	2.62	.7854	.5463	.2391	3.82	4.53	.81
1¼	1.084	.083	14	3.927	3.405	1.227	.9229	.3041	3.056	3.524	1.02
1½	1.31	.095	13	4.712	4.115	1.767	1.3478	.4192	2.546	2.916	1.40
1¾	1.532	.109	12	5.498	4.813	2.405	1.8433	.5617	2.183	2.493	1.87
2	1.782	.109	12	6.283	5.598	3.1416	2.494	.6476	1.91	2.144	2.17
2¼	2.032	.109	12	7.069	6.384	3.976	3.2429	.7331	1.698	1.88	2.45
2½	2.26	.12	11	7.854	7.1	4.9087	4.011	.8977	1.528	1.69	3.00
2¾	2.51	.12	11	8.639	7.885	5.94	4.948	.992	1.389	1.522	3.31
3	2.76	.12	11	9.425	8.67	7.069	5.983	1.086	1.273	1.384	3.63
3¼	2.982	.134	10	10.21	9.366	8.295	6.984	1.311	1.175	1.275	4.39
3½	3.232	.134	10	10.99	10.151	9.621	8.214	1.407	1.091	1.181	4.74
3¾	3.482	.134	10	11.78	10.936	11.044	9.522	1.52	1.018	1.096	5.09
4	3.704	.148	9	12.56	11.634	12.566	10.75	1.81	.955	1.031	6.00

Table No. 23.

Wrought-Iron Welded Steam, Gas, and Water Pipe.

Table of Standard Dimensions.

Diameter.			Thickness.	Circumference.		Transverse Areas.			Length of Pipe per Sq. Foot of		Length of Pipe Containing One Cubic Foot.	Nominal Weight per Foot.	Number of Threads per Inch of Screw.
Nominal Int'l.	Actual Ext'l.	Actual Int'l.		Ext'l.	Int'l.	Ext'l.	Int'l.	Metal.	Ext'l Surface	Int'l Surface.			
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet.	Feet.	Feet.	Lbs.	. . .
1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27
1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1249	7.075	10.49	1383.3	.42	18
3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18
1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14
3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14
1	1.315	1.048	.134	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	11½
1¼	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11½
1½	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	2.678	11½
2	2.375	2.067	.154	7.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	3.609	11½
2½	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8
3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8
3½	4.	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8
4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.949	11.31	10.665	8
4½	5.	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.34	8
5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8

Table No. 23.

Wrought-Iron Welded Steam, Gas, and Water Pipe.

Table of Standard Dimensions.

Diameter.			Thickness.	Circumference.		Transverse Areas.			Length of Pipe per Sq. Foot of		Length of Pipe Containing One Cubic Foot.	Nominal Weight per Foot.	Number of Threads per Inch of Screw.
Nominal Int'l.	Actual Ext'l.	Actual Int'l.		Ext'l.	Int'l.	Ext'l.	Int'l.	Metal.	Ext'l Surface	Int'l Surface.			
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet.	Feet.	Feet.	Lbs.	. . .
6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8
8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8
9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8
10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8
11	12.	11.25	.375	37.699	35.343	113.098	99.402	13.696	.318	.339	1.456	45.95	8
12	12.75	12.	.375	40.055	37.7	127.677	113.098	14.579	.299	.319	1.27	48.985	8
13	14.	13.25	.375	43.982	41.626	153.938	137.887	16.051	.273	.288	1.04	53.921	8
14	15.	14.25	.375	47.124	44.768	176.715	159.485	17.23	.255	.268	.903	57.893	8
15	16.	15.25	.375	50.265	47.909	201.062	182.655	18.407	.239	.250	.788	61.77	8
..	18.	17.25	.375	56.549	54.192	254.47	233.706	20.764	.212	.221	.616	69.66	..
..	20.	19.25	.375	62.832	60.476	314.16	291.04	23.12	.191	.198	.495	77.57	..
..	22.	21.25	.375	69.115	66.759	380.134	354.657	25.477	.174	.179	.406	85.47	..
..	24.	23.25	.375	75.398	73.042	452.39	424.558	27.832	.159	.164	.339	93.37	..

Table No. 24.

Standard Plate Washers.

Diameter.	Thickness, Wire Gage.	Size of Hole.	Size of Bolt.
9/16	No. 18 (3/64)	1/4	3/16
3/4	" 16 (1/16)	5/16	1/4
7/8	" 16 "	3/8	5/16
1	" 14 (5/64)	7/16	3/8
1 1/4	" 14 "	1/2	7/16
1 3/8	" 12 (3/32)	9/16	1/2
1 1/2	" 12 "	5/8	9/16
1 3/4	" 10 (1/8)	11/16	5/8
2	" 10 "	13/16	3/4
2 1/4	" 10 "	15/16	7/8
2 1/2	" 9 (5/32)	1 1/16	1
2 3/4	" 9 "	1 1/4	1 1/8
3	" 9 "	1 3/8	1 1/4
3 1/2	" 8 (11/64)	1 1/2	1 3/8
3 3/4	" 8 "	1 5/8	1 1/2
3 3/4	" 8 "	1 3/4	1 5/8
4	" 8 "	1 7/8	1 3/4
4 1/4	" 8 "	2	1 7/8
4 1/2	" 8 "	2 1/8	2
4 3/4	" 6 (7/32)	2 3/8	2 1/4
5	" 6 "	2 5/8	2 1/2

Table No. 25.

Standard Sizes of Heads of Rivets.

Tank Rivets.

Size of Rivet.	Button Heads.		Flat Heads.		Countersunk Heads.	
	Wide.	Thick.	Wide.	Thick.	Wide.	Thick.
1/8 diam.	9/32	5/64	9/32	3/64	1/4	1/16
3/16 ″	13/32	3/32	3/8	1/16	11/32	3/32
1/4 ″	15/32	5/32	17/32	3/32	15/32	5/32 full.
5/16 ″	9/16	3/16	21/32	7/64	9/16	3/16 ″
3/8 ″ sct.	5/8	1/4	23/32	5/32	5/8	7/32
3/8 ″ ex.	11/16	5/16	25/64	11/64	11/16	1/4
7/16 ″	25/32	3/8	13/16	11/64	3/4	9/32
1/2 ″	7/8	3/8	7/8	5/32	7/8	5/16

Table No. 26.

Boiler Rivets.

Size of Rivet.	Button Heads.		Cone Heads.		Countersunk Heads.	
	Wide.	Thick.	Wide.	Thick.	Wide.	Thick.
1/2 in.	7/8	3/8	7/8	15/32	7/8	1/4
9/16 ″	15/16	3/8	31/32	31/64	15/16	9/32
5/8 ″	1 1/16	7/16	1 1/16	9/16	1 1/8	9/23
11/16 ″	1 1/8	1/2	1 1/8	39/64	1 3/16	5/16
3/4 ″	1 1/4	9/16	1 1/4	21/32	1 1/4	3/8
7/8 ″	1 7/16	3/4	1 7/16	3/4	1 3/8	7/16
1 ″	1 5/8	3/4	1 5/8	27/32	1 5/8	1/2
1 1/8 ″	1 3/4	13/16	1 27/32	15/16	1 7/8	9/16
1 1/4 ″	2	1	2 1/16	1 1/32	2 1/8	5/8

Table No. 27.

Weights of Steel Plates Per Square Foot.

Inches.	Steel.	Inches.	Steel.	Inches.	Steel.
1-16	2.551	35-64	22.329	1. 1-32	42.106
5-64	3.189	9-16	22.966	1. 3-64	42.744
3-32	3.827	37-64	23.604	1. 1-16	43.381
7-64	4.465	19-32	24.242	1. 5-64	44.019
1-8	5.103	39-64	24.880	1. 3-32	44.657
9-64	5.741	5-8	25.518	1. 7-64	45.295
5-32	6.379	41-64	26.156	1. 1-8	45.933
11-64	7.017	21-32	26.794	1. 9-64	46.571
3-16	7.655	43-64	27.432	1. 5-32	47.209
13-64	8.293	11-16	28.070	1.11-64	47.847
7-32	8.931	45-64	28.708	1. 3-16	48.485
15-64	9.569	23-32	29.346	1.13-64	49.123
1-4	10.207	47-64	29.984	1. 7-32	49.761
17-64	10.845	3-4	30.622	1.15-64	50.399
9-32	11.483	49-64	31.260	1. 1-4	51.037
19-64	12.121	25-32	31.898	1. 9-32	52.313
5-16	12.759	51-64	32.536	1. 5-16	53.589
21-64	13.397	13-16	33.174	1.11-32	54.865
11-32	14.035	53-64	33.812	1. 3-8	56.141
23-64	14.673	27-32	34.450	1.13-32	57.417
3-8	15.311	55-64	35.088	1. 7-16	58.693
25-64	15.949	7-8	35.726	1.15-32	59.969
13-32	16.587	57-64	36.364	1. 1-2	61.245
27-64	17.225	29-32	37.002	1.17-32	62.521
7-16	17.863	59-64	37.640	1. 9-16	63.796
29-64	18.501	15-16	38.278	1.19-32	65.072
15-32	19.139	61-64	38.916	1. 5-8	66.348
31-64	19.777	31-32	39.554	1.21-32	67.624
1-2	20 415	63-64	40.192	1.11-16	68.900
33-64	21.053	1.	40.83	1.23-32	70.176
17-32	21.691	1. 1-64	41.467	1. 3-4	71.452

Table No. 28.

Allowance for Dome Plates.

Diameter of Dome.	Diameter of Shell.								
	30	36	42	48	54	60	66	72	80
	In.	In.	In.	In.	In.	In.	In.	In.	In.
20	6¼	5½	5¼	....	....	....	....	....	....
22	7¼	6¼	5¾	5¼	....	....	....	....	....
24	8½	7¼	6½	5¾	5½	....	....	....	....
26	....	8¼	7¼	6½	6	....	....	....	....
28	....	9½	8	7¼	6½	6	....	....	....
30	....	10¾	9	8	7¼	6¾	6¼	5¾	5¼
32	....	....	10	8¾	8	7¼	6¾	6¼	5¾
34	....	....	....	9¾	8¾	8	7¼	7	6
36	....	....	....	10¾	9½	8½	8	7¼	6½
38	....	....	....	....	10¼	9½	8¾	8	7
40	....	....	....	....	....	10¼	9½	9¾	7½
42	....	....	....	....	....	11¼	10¼	10½	8
44	....	....	....	....	....	....	11	10	9
46	....	....	....	....	....	....	12¼	10¾	9½
48	....	....	....	....	....	....	13	11½	10

Having the diameter of the dome and the shell to which it is to be attached, the width of the dome plate can be ascertained by adding the allowance named above to finished length of dome.

This allows for single row of rivets on the flange. For double row of rivets add two inches to each of the above allowances. This is based on plates ⅝ inch and under.

Table No. 29.

Table of Allowances for Overweight for Rectangular or Circular Plates, due to Bending of Rolls.

The Weight of 1 Cubic Inch of Rolled Steel is Assumed to be .2833 Pound.

Plates Under ¼ Inch in Thickness.

Thickness of Plate.	Width of Plate.	
	Up to 50 in.	50 in. and above.
⅛ in. up to 5/32 in.	10 per cent.	15 per cent.
5/32 " 3/16 "	8½ "	12½ "
3/16 " ¼ "	7 "	10 "

Thickness of Plate.	Width of Plate.		
	Up to 75 in.	75 in. to 100 in.	Over 100 in.
¼ inch	10 per cent.	14 per cent.	18 per cent.
5/16 "	8 "	12 "	16 "
⅜ "	7 "	10 "	13 "
7/16 "	6 "	8 "	10 "
½ "	5 "	7 "	9 "
9/16 "	4½ "	6½ "	8½ "
⅝ "	4 "	6 "	8 "
Over ⅝ "	3½ "	5 "	6½ "

Table No. 30.

Weight of Circular Plates of Steel.

Diam. in Inches.	Thickness of Plate in Inches.														
	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
16	7	11	14	18	22	25	29	...	...	...	...	....	....	....	....
18	9	14	18	23	27	32	36	...	...	...	...	....	....	....	....
20	11	17	23	28	34	39	45	...	...	...	...	....	....	....	....
22	14	20	27	34	41	48	55	...	...	...	...	....	....	....	....
24	16	24	32	41	49	57	65	...	...	...	...	....	....	....	....
26	19	29	38	47	57	67	76	...	...	...	...	....	....	....	....
28	23	33	44	55	66	77	88	...	...	...	...	....	....	....	....
30	25	38	51	63	76	89	101	...	...	...	...	....	....	....	....
32	29	43	58	72	86	101	115	...	...	...	...	....	....	....	....
34	33	49	65	81	98	114	130	...	...	...	...	....	....	....	....
36	37	55	73	91	109	128	146	162	178	194	210	....	....	....	....
38	41	61	81	102	123	142	163	182	201	220	239	....	....	....	....
40	45	68	90	113	135	158	180	203	225	247	269	....	....	....	....
42	50	75	99	124	149	174	199	223	248	272	297	....	....	....	....
44	55	82	109	136	164	191	218	245	273	301	329	....	....	....	....
46	60	89	119	149	179	209	239	268	299	328	358	....	....	....	....
48	65	97	130	162	195	227	259	292	324	357	390	....	....	....	....
50	..	106	141	176	211	246	281	317	352	387	422	....	....	....	....
52	..	114	152	190	228	266	304	343	381	419	457	....	....	....	....
54	..	123	164	205	246	287	328	369	410	451	492	....	....	....	....
56	..	132	177	221	265	309	353	397	441	485	530	....	....	....	....
58	..	142	189	237	284	331	379	426	473	521	568	....	....	....	....
60	..	...	204	254	305	356	408	457	510	561	612	....	....	....	....
62	..	...	219	273	328	382	437	492	546	601	656	....	....	....	....
64	..	...	233	291	349	407	466	524	582	640	699	....	....	....	....
66	..	...	248	310	371	433	495	557	619	681	743	....	....	....	....
68	..	...	263	329	394	460	526	591	657	723	789	....	....	....	....
70	..	...	279	348	418	487	557	627	696	766	836	....	....	....	....
72	..	...	295	368	442	516	589	663	737	810	884	....	....	....	....
74	..	...	311	389	467	545	623	700	778	856	934	....	....	....	....
76	..	...	328	410	492	575	657	739	821	903	985	1067	1149	1251	1313
78	..	...	346	432	519	605	692	778	865	951	1038	1124	1210	1297	1383
80	..	...	367	458	550	641	733	830	917	1008	1100	1192	1283	1384	1476
82	..	...	388	485	582	679	776	872	969	1066	1163	1260	1357	1454	1551
84	..	...	407	509	610	712	814	916	1017	1119	1221	1322	1424	1526	1628
86	..	...	427	533	640	746	853	960	1066	1173	1280	1386	1493	1599	1706
88	..	...	447	558	670	782	893	1005	1117	1228	1340	1452	1563	1675	1787
90	..	...	467	584	701	817	934	1051	1168	1285	1401	1518	1635	1752	1869
92	..	...	...	610	732	854	976	1098	1220	1342	1463	1586	1708	1830	1953
94	..	...	...	637	764	892	1019	1146	1274	1401	1529	1656	1783	1911	2038

Note.—Extra weights to be added for wide spaces.

TABLE No. 31.

Wrought Iron, Steel, Copper and Brass Plates.

Birmingham Gage.

No. of Gage.	Thickness, Inches.	Weight per Square Foot, Lbs.			
		Iron.	Steel.	Copper.	Brass.
0000	0.454 or 7/16 full...	18.2167	18.4596	20.5652	19.4312
000	0.425	17.0531	17.2805	19.2525	18.1900
00	0.38 or 3/8 full...	15.2475	15.4508	17.2140	16.2640
0	0.34 or 1/3 full...	13.6425	13.8244	15.4020	14.5520
1	0.3	12.0375	12.1980	13.5900	12.8400
2	0.284	11.3955	11.5474	12.8652	12.1552
3	0.259 or 1/4 full...	10.3924	10.5309	11.7327	11.0852
4	0.238	9.5497	9.6771	10.7814	10.1864
5	0.22	8.8275	8.9452	9.9660	9.4160
6	0.203 or 1/5 full...	8.1454	8.2540	9.1959	8.6884
7	0.18 or 3/16 light..	7.2225	7.3188	8.1540	7.7040
8	0.165 or 1/6 light ..	6.6206	6.7089	7.4745	7.0620
9	0.148 or 1/7 full...	5.9385	6.0177	6.7044	6.3344
10	0.134	5.3767	5.4484	6.0702	5.7352
11	0.12 or 1/8 light..	4.8150	4.8792	5.4360	5.1360
12	0.109	4.3736	4.4319	4.9377	4.6652
13	0.095 or 1/10 light..	3.8119	3.8627	4.3035	4.0660
14	0.083	3.3304	3.3748	3.7599	3.5524
15	0.072	2.8890	2.9275	3.2616	3.0816
16	0.065	2.6081	2.6429	2.9445	2.7820
17	0.058	2.3272	2.3583	2.6274	2.4824
18	0.049 or 1/20 light..	1.9661	1.9923	2.2197	2.0972
19	0.042	1.6852	1.7077	1.9026	1.7976
20	0.035	1.4044	1.4231	1.5855	1.4980
21	0.032	1.2840	1.3011	1.4496	1.3696
22	0.028	1.1235	1.1385	1.2684	1.1984
23	0.025 or 1/40	1.0031	1.0165	1.1325	1.0700
24	0.022	0.8827	0.8945	0.9966	0.9416
25	0.02 or 1/50	0.8025	0.8132	0.9060	0.8560
26	0.018	0.7222	0.7319	0.8154	0.7704
27	0.016	0.6420	0.6506	0.7248	0.6848
28	0.014	0.5617	0.5692	0.6342	0.5992
29	0.013	0.5216	0.5286	0.5889	0.5564
30	0.012	0.4815	0.4879	0.5436	0.5136
31	0.01 or 1/100	0.4012	0.4066	0.4530	0.4280
32	0.009	0.3611	0.3659	0.4077	0.3852
33	0.008	0.3210	0.3253	0.3624	0.3424
34	0.007	0.2809	0.2846	0.3171	0.2996
35	0.005 or 1/200	0.2006	0.2033	0.2265	0.2140
36	0.004 or 1/250	0.1605	0.1626	0.1812	0.1712
	1.00 inch thick...	41.5696	42.1236	46.9308	44.3408

Table No. 32.

Weight of Round and Square Iron.

Thickness or Diam.	Weight of Square.	Weight of Round.	Thickness or Diam.	Weight of Square.	Weight of Round.
3/16	.120	.094	1/16	14.47	11.36
1/4	.213	.167	1/8	15.36	12.06
5/16	.332	.261	3/16	16.28	12.79
3/8	.478	.375	1/4	17.22	13.52
7/16	.651	.511	5/16	18.19	14.29
1/2	.851	.668	3/8	19.19	15.07
9/16	1.076	.845	7/16	20.21	15.87
5/8	1.329	1.044	1/2	21.26	16.70
11/16	1.608	1.263	9/16	22.34	17.55
3/4	1.914	1.503	5/8	23.44	18.41
13/16	2.246	1.764	11/16	24.57	19.30
7/8	2.605	2.046	3/4	25.73	20.21
15/16	2.990	2.348	13/16	26.91	21.14
1	3.402	2.672	7/8	28.12	22.09
1/16	3.841	3.017	15/16	29.36	23.06
1/8	4.306	3.382	3	30.62	24.05
3/16	4.798	3.768	1/16	31.91	25.06
1/4	5.316	4.175	1/8	33.23	26.10
5/16	5.861	4.603	3/16	34.57	27.15
3/8	6.432	5.052	1/4	35.94	28.23
7/16	7.030	5.521	5/16	37.33	29.32
1/2	7.655	6.012	3/8	38.75	30.43
9/16	8.306	6.524	7/16	40.20	31.57
5/8	8.984	7.056	1/2	41.68	32.74
11/16	9.688	7.609	9/16	43.17	33.91
3/4	10.419	8.183	5/8	44.71	35.12
13/16	11.177	8.778	11/16	46.26	36.33
7/8	11.961	9.394	3/4	47.84	37.57
15/16	12.772	10.031	13/16	49.45	38.84
2	13.61	10.69	7/8	51.09	40.13
			15/16	52.75	41.43

Table No. 33.

Weight of Flat Iron Per Lineal Foot.

Width, Inches.	Thickness in Inches.									
	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2	.211	.361	.422	.491	.634	.....	.....	.....	.....	.....
5/8	.260	.420	.510	.640	.784	.90	.....	.....	.....	.....
3/4	.316	.471	.633	.790	.950	1.26	1.58	.....	.....	.....
7/8	.370	.551	.730	.915	1.09	1.46	1.82	2.19	.....	.....
1	.421	.623	.832	1.04	1.25	1.67	2.08	2.50	2.92	.....
1 1/8	.475	.700	.940	1.17	1.41	1.88	2.34	2.81	3.28	3.75
1 1/4	.524	.782	1.04	1.30	1.56	2.08	2.60	3.12	3.64	4.17
1 3/8	.574	.860	1.15	1.43	1.72	2.29	2.86	3.44	4.01	4.58
1 1/2	.631	.940	1.25	1.56	1.88	2.50	3.13	3.75	4.38	5.00
1 5/8	.682	1.02	1.35	1.69	2.03	2.71	3.38	4.01	4.74	5.42
1 3/4	.730	1.09	1.46	1.82	2.19	2.92	3.65	4.37	5.10	5.83
2	.831	1.24	1.67	2.08	2.50	3.33	4.17	5.00	5.83	6.67
2 1/4	.945	1.41	1.88	2.34	2.81	3.75	4.69	5.63	6.51	7.50
2 1/2	1.04	1.56	2.08	2.60	3.12	4.17	5.21	6.25	7.29	8.33
2 3/4	1.14	1.72	2.29	2.86	3.44	4.59	5.73	6.87	8.02	9.17
3	1.25	1.87	2.50	3.12	3.75	5.00	6.25	7.50	8.75	10.00
3 1/4	1.35	2.03	2.71	3.38	4.07	5.42	6.77	8.12	9.48	10.83
3 1/2	1.46	2.19	2.92	3.65	4.38	5.83	7.29	8.75	10.21	11.61
3 3/4	1.56	2.34	3.12	3.90	4.69	6.25	7.81	9.37	10.94	12.50
4	1.67	2.50	3.33	4.17	5.00	6.67	8.33	10.00	11.67	13.33
4 1/2	1.87	2.81	3.75	4.69	5.63	7.50	9.38	11.25	13.13	15.60
5	2.08	3.13	4.17	5.21	6.25	8.34	10.42	12.50	14.59	16.67
6	2.50	3.75	5.00	6.25	7.50	10.00	12.50	15.00	17.50	20.00

Table No. 34.

Estimated Weights of Black Sheets.

U. S. Standard Gage. Weight per Sheet in Pounds.

U. S. Gauge	10	12	14	15	16	18	20	22	24	26	27	28	29	30
Lbs. per Sq Ft	5.625	4.375	3.125	2.8125	2.50	2.00	1.50	1.25	1.00	.75	.6875	.625	.5625	.50
Thickn's (inches)	9/64	7/64	5/64	9/128	1/16	1/20	3/80	1/32	1/40	3/160	11/640	1/64	9/640	1/80
24 x 96	90.00	70.00	50.00	45.00	40.00	32.00	24.00	20.00	16.00	12.00	11.00	10.00	9.00	8.00
101	94.69	73.65	52.60	47.34	42.08	33.67	25.25	21.04	16.84	12.63	11.57	10.52	9.47	8.42
108	101.25	78.75	56.25	50.63	45.00	36.00	27.00	22.50	18.00	13.50	12.38	11.25	10.13	9.00
120	112.50	87.50	62.50	56.25	50.00	40.00	30.00	25.00	20.00	15.00	13.75	12.50	11.25	10.00
138	129.38	100.63	71.88	64.69	57.50	46.00	34.50	28.75	23.00	17.25	15.81	14.38	.....	.....
144	135.00	105.00	75.00	67.50	60.00	48.00	36.00	30.00	24.00	18.00	16.50	15.00	.....	.....
26 x 96	97.50	75.83	54.17	48.75	43.33	34.67	26.00	21.67	17.34	13.00	11.92	10.83	9.75	8.67
101	102.58	79.78	57.00	51.29	45.59	36.47	27.35	22.79	18.24	13.68	12.54	11.40	10.26	9.12
108	109.69	85.31	60.94	54.84	48.75	39.00	29.25	24.37	19.50	14.63	13.41	12.19	10.97	9.75
120	121.88	94.79	67.71	60.94	54.17	43.33	32.50	27.08	21.67	16.25	14.90	13.54	12.19	10.83
138	140.16	109.01	77.87	70.08	62.29	49.83	37.38	31.15	24.92	18.69	17.13	15.57	.....	.....
144	146.25	113.75	81.25	73.13	65.00	52.00	39.00	32.50	26.00	19.50	17.88	16.25	.....	.....
28 x 96	105.00	81.67	58.33	52.50	46.67	37.33	28.00	23.33	18.67	14.00	12.83	11.67	10.50	9.33
101	110.47	85.92	61.37	55.23	49.09	39.28	29.46	24.55	19.64	14.73	13.50	12.27	11.05	9.82
108	118.13	91.88	65.63	59.06	52.50	42.00	31.50	26.25	21.00	15.75	14.44	13.13	11.81	10.50
120	131.25	102.08	72.92	65.63	58.33	46.67	35.00	29.17	23.33	17.50	16.04	14.58	13.13	11.67
30 x 96	112.50	87.50	62.50	56.25	50.00	40.00	30.00	25.00	20.00	15.00	13.75	12.50	11.25	.....
101	118.36	92.06	65.76	59.18	52.60	42.08	31.56	26.30	21.04	15.78	14.47	13.15	.....	.....
108	126.56	98.44	70.31	62.69	56.25	45.00	33.75	28.12	22.50	16.88	15.47	14.06	.....	.....
120	140.63	109.38	78.13	70.31	62.50	50.00	37.50	31.25	25.00	18.75	17.19	15.63	.....	.....
138	161.72	125.78	89.84	80.86	71.88	57.50	43.13	35.94	28.75	21.56	19.77	17.97	.....	.....
144	168.75	131.25	93.75	84.38	75.00	60.00	45.00	37.50	30.00	22.50	20.63	18.75	.....	.....
36 x 77	108.28	84.22	60.17	54.14	48.13	38.50	28.88	24.06	19.25	14.44	13.23	12.03	.....	.....
96	135.00	105.00	75.00	67.50	60.00	48.00	36.00	30.00	24.00	18.00	16.50	15.00	.....	.....
108	151.88	118.13	84.38	75.94	67.50	54.00	40.50	33.75	27.00	20.25	18.56	16.88	.....	.....
120	168.75	131.25	93.75	84.38	75.00	60.00	45.00	37.50	30.00	22.50	20.63	18.75	.....	.....
138	194.06	145.47	107.81	97.03	86.25	69.00	51.75	43.13	34.50	25.88	23.72	21.56	.....	.....
144	202.50	157.50	112.50	101.25	90.00	72.00	54.00	45.00	36.00	27.00	24.75	22.50	.....	.....
42 x 77	126.33	98.26	70.18	63.16	56.14	44.92	33.69	28.07	22.46	16.84	15.44	14.04	.....	.....
96	157.50	122.50	87.50	78.75	70.00	56.00	42.00	35.00	28.00	21.00	19.25	17.50	.....	.....
108	177.19	137.81	98.44	88.59	78.75	63.00	47.25	39.37	31.50	23.63	21.66	19.69	.....	.....
120	196.88	153.13	109.38	98.44	87.50	70.00	52.51	43.75	35.00	26.25	24.06	21.88	.....	.....
138	226.41	176.09	125.78	113.20	100.63	80.50	60.38	50.31	40.25	30.19	27.67	25.16	.....	.....
144	236.25	183.75	131.25	118.13	105.00	84.00	63.00	52.50	42.00	31.50	28.88	26.24	.....	.....
48 x 77	144.38	112.29	80.21	72.19	64.17	51.33	38.50	32.08	25.67	19.25	17.65	16.04	.....	.....
96	180.00	140.00	100.00	90.00	80.00	64.00	48.00	40.00	32.00	24.00	22.00	20.00	.....	.....
108	202.50	157.50	112.50	101.25	90.00	72.00	54.00	45.00	36.00	27.00	24.75	22.50	.....	.....
120	225.00	175.00	125.00	112.50	100.00	80.00	60.00	50.00	40.00	30.00	27.50	25.00	.....	.....
138	258.75	201.25	143.75	129.38	115.00	92.00	69.00	57.50	46.00	34.50	31.63	28.75	.....	.....
144	270.00	210.00	150.00	135.00	120.00	96.00	72.00	60.00	48.00	36.00	33.00	30.00	.....	.....
54 x 77	162.42	126.33	90.26											
96	201.50	157.50	112.50											
108	227.82	177.20	126.57											
120	253.13	196.88	140.63											
138	291.09	218.21	161.71											
144	303.75	236.25	168.75											
60 x 77	180.48	140.36												
96	225.00	175.00												
108	253.12	196.88												
120	281.26	219.36												
138	328.44	251.56												
144	337.50	262.50												

NOTE.

Above estimated weights are based on U. S. standard gage for Iron. For Steel, add 2 per cent. These figures are given for convenience in estimating only, and may vary somewhat in actual practice. The sizes below the heavy black line will probably considerably exceed the weights given, and it is safe, therefore, to allow for an overweight of at least 10 per cent.

Table No. 35.

Weights of Steel Angles

(With Fillet)

Per Lineal Foot in Pounds.

Size in Inches.	Thickness in Inches.														
	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
8 x 8	....	....	....	....	....	....	26.4	29.5	32.7	35.8	38.9	42.0	45.0	48.0	51.0
7 x 3½	....	....	....	....	....	15.0	17.0	19.0	21.0	13.0	24.9	26.8	28.7	30.5	32.3
6 x 6	....	....	....	....	14.8	17.2	19.6	21.9	24.2	26.5	28.7	30.9	33.1	35.3	37.4
6 x 4	....	....	....	....	12.3	14.3	16.2	18.1	20.0	21.8	23.6	25.4	27.2	28.9	30.6
6 x 3½	....	....	....	....	11.7	13.5	15.3	17.1	18.9	20.6	22.3	24.0	25.7	27.3	28.9
5 x 5	....	....	....	....	12.3	14.3	16.2	18.1	20.0	21.8	23.6	25.4	27.2	28.9	30.6
5 x 4	....	....	....	....	11.0	12.8	14.5	16.2	17.8	19.5	21.1	22.6	24.2	....	....
5 x 3½	....	....	....	....	10.4	12.0	13.6	15.2	16.8	18.3	19.9	21.3	22.7	....	....
5 x 3	....	....	....	8.2	9.8	11.3	12.8	14.2	15.7	17.1	18.5	19.9	....	....	....
4½ x 3	....	....	....	....	9.1	10.5	11.9	13.3	14.6	15.9	17.2	18.5	....	....	....
4 x 4	....	5.2	6.6	8.2	9.8	11.3	12.8	14.3	15.7	17.1	18.5	19.9	....	....	....
4 x 3½	....	....	....	....	9.1	10.5	11.9	13.3	14.6	15.9	17.2	18.5	....	....	....
4 x 3	....	....	....	7.1	8.5	9.8	11.1	12.3	13.6	14.8	16.0	17.1	....	....	....
3½ x 3½	....	....	5.7	7.1	8.5	9.8	11.1	12.3	13.6	14.8	16.0	17.1	....	....	....
3½ x 3	....	....	....	6.6	7.8	9.1	10.2	11.4	12.5	13.6	14.7	15.7	....	....	....
3½ x 2½	....	....	4.9	6.1	7.2	8.3	9.4	10.4	11.4	12.4	....	....	....	....	....
3¼ x 3¼	....	....	....	....	7.8	9.0	10.2	11.4	12.5	13.6	14.7	....	....	....	....
3¼ x 2	....	....	4.3	5.3	6.2	7.2	8.1	9.0	....	....	....	....	....	....	....
3 x 3	2.6	....	4.9	6.1	7.2	8.4	9.4	10.4	12.4	12.4	13.4	14.4	....	....	....
3 x 2½	....	....	4.5	5.5	6.6	7.6	8.5	9.5	....	....	....	....	....	....	....
3 x 2	....	3.1	4.1	5.0	5.9	6.8	7.7	....	....	....	....	....	....	....	....
2¾ x 2¾	2.4	3.5	4.5	5.5	6.6	7.6	8.5	....	....	....	....	....	....	....	....
2½ x 2½	2.1	3.0	4.1	5.0	5.9	6.8	7.7	8.5	9.3	10.1	....	....	....	....	....
2½ x 2	....	2.8	3.7	4.5	5.3	6.1	6.8	....	....	....	....	....	....	....	....
2½ x 1¾	....	2.6	....	....	....	....	....	....	....	....	....	....	....	....	....
2½ x 1½	....	2.4	3.2	3.9	4.6	5.3	6.0	....	....	....	....	....	....	....	....
2¼ x 2¼	1.9	2.8	3.7	4.5	5.3	6.1	6.8	....	....	....	....	....	....	....	....
2¼ x 1½	....	2.3	3.0	3.7	4.3	5.0	5.5	....	....	....	....	....	....	....	....
2 x 2	1.7	2.5	3.2	4.0	4.7	5.3	....	....	....	....	....	....	....	....	....
2 x 1½	....	2.1	2.8	3.4	4.0	....	....	....	....	....	....	....	....	....	....
2 x 1¼	....	2.1	2.7	3.3	3.8	....	....	....	....	....	....	....	....	....	....
1¾ x 1¾	1.4	2.1	2.8	3.4	4.0	4.6	....	....	....	....	....	....	....	....	....
1¾ x 1½	....	2.0	2.6	3.3	3.9	....	....	....	....	....	....	....	....	....	....
1½ x 1½	1.2	1.8	2.4	2.9	3.4	....	....	....	....	....	....	....	....	....	...
1⅜ x 1	1.0	....	1.8	....	....	....	....	....	....	....	....	....	....	....	....
1⅜ x ⅞	1.0	1.4	1.9	....	....	....	....	....	....	....	....	....	....	....	....
1¼ x 1¼	1.0	1.5	1.9	2.4	....	....	....	....	....	....	....	....	....	....	....
1⅛ x 1⅛	0.9	1.3	1.7	2.1	....	....	....	....	....	....	....	....	....	....	....
1 x 1	0.8	1.2	1.5	....	....	....	....	....	....	....	....	....	....	....	....
1 x ¾	....	1.0	....	....	....	....	....	....	....	....	....	....	....	....	....
1 x ⅝	0.7	1.0	....	....	....	....	....	....	....	....	....	....	....	....	....
⅞ x ⅞	0.7	1.0	....	....	....	....	....	....	....	....	....	....	....	....	....
¾ x ¾	0.6	0.8	....	....	....	....	....	....	....	....	....	....	....	....	....
⅝ x ⅝	0.5	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TABLE NO. 36.

Number of Rivets in 100 Pounds.

Lengths.	⅜ In.	7/16 In.	½ In.	9/16 In.	⅝ In.	11/16 In.	¾ In.	⅞ In.
¾	1965	1429	1092	944	665	...	...	...
⅞	1848	1335	1027	846	597	...	...	...
1	1692	1222	940	763	538	450	...	...
1⅛	1512	1092	840	726	512	415	...	...
1¼	1437	1036	797	691	487	389	356	228
1⅜	1368	988	760	653	460	370	329	211
1½	1300	949	730	624	440	357	280	180
1⅝	1260	924	711	596	420	340	271	174
1¾	1200	900	693	553	390	325	262	169
1⅞	1156	840	648	532	375	312	257	165
2	1100	789	608	511	360	297	243	156
2⅛	1031	744	573	502	354	289	237	152
2¼	999	721	555	491	347	280	232	149
2½	945	682	525	475	335	260	220	141
2¾	900	650	500	443	312	242	208	133
3	828	598	460	411	290	224	197	127
3¼	779	562	433	379	267	212	180	115
3½	743	536	413	352	248	201	169	108
3¾	715	513	395	341	241	192	160	102
4	....	...	...	326	230	184	158	99
4¼	....	....	....	312	220	177	150	96
4½	....	....	....	298	210	171	146	94
4¾	....	....	....	284	200	166	138	89
5	....	....	....	270	190	161	135	87
5¼	....	....	....	256	180	156	130	84
5½	....	....	....	244	172	151	124	80
5¾	....	....	....	233	164	145	120	77
6	....	....	....	223	157	140	115	74
6¼	....	....	....	213	150	138	111	71
6½	....	....	....	207	146	134	107	69
6¾	....	....	....	203	143	129	104	67
7	....	....	....	198	140	125	100	64

Length of rivets are measured under the head.

TABLE NO. 37.

Weight of One Cubic Foot of Water at Various Temperatures.

Temp., Degrees F.	Weight per Cubic Foot.	Temp., Degrees F.	Weight per Cubic Foot.	Temp., Degrees F.	Weight per Cubic Foot.
32	62.418	105	61.960	185	60.430
35	62.422	110	61.868	190	60.314
39.1	62.425	115	61.807	195	60.198
40	62.425	120	61.715	200	60.081
45	62.422	125	61.654	205	59.930
50	62.409	130	61.563	210	59.820
55	62.394	135	61.472	212	59.760
60	62.372	140	61.381	212	59.640
65	62.344	145	61.291	230	59.360
70	62.313	150	61.201	250	58.780
75	62.275	155	61.096	270	58.150
80	62.232	160	60.991	290	57.590
85	62.182	165	60.843	298	57.270
90	62.133	170	60.783	338	56.140
95	62.074	175	60.665	366	55.290
100	62.022	180	60.548	390	54.540

The first valve for 212 degrees is by formula, the second by measurement.

TABLE NO. 38.

Equivalents of Millimetres in Inches.

Inches = Millimetres × .03937079.

Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
1	.0394	46	1.8111	91	3.5827	136	5.3544
2	.0787	47	1.8504	92	3.6221	137	5.3938
3	.1181	48	1.8898	93	3.6615	138	5.4332
4	.1575	49	1.9292	94	3.7009	139	5.4725
5	.1969	50	1.9685	95	3.7402	140	5.5119
6	.2362	51	2.0079	96	3.7796	141	5.5513
7	.2756	52	2.0473	97	3.8190	142	5.5907
8	.3150	53	2.0867	98	3.8583	143	5.6300
9	.3543	54	2.1260	99	3.8977	144	5.6694
10	.3937	55	2.1654	100	3.9371	145	5.7088
11	.4331	56	2.2048	101	3.9764	146	5.7481
12	.4724	57	2.2441	102	4.0158	147	5.7875
13	.5118	58	2.2835	103	4.0552	148	5.8269
14	.5512	59	2.3229	104	4.0946	149	5.8662
15	.5906	60	2.3622	105	4.1339	150	5.9056
16	.6299	61	2.4016	106	4.1733	151	5.9450
17	.6693	62	2.4410	107	4.2127	152	5.9844
18	.7087	63	2.4804	108	4.2520	153	6.0237
19	.7480	64	2.5197	109	4.2914	154	6.0631
20	.7874	65	2.5591	110	4.3308	155	6.1025
21	.8268	66	2.5985	111	4.3702	156	6.1418
22	.8662	67	2.6378	112	4.4095	157	6.1812
23	.9055	68	2.6772	113	4.4489	158	6.2206
24	.9449	69	2.7166	114	4.4883	159	6.2600
25	.9843	70	2.7560	115	4.5276	160	6.2993
26	1.0236	71	2.7953	116	4.5670	161	6.3387
27	1.0630	72	2.8347	117	4.6064	162	6.3781
28	1.1024	73	2.8741	118	4.6458	163	6.4174
29	1.1418	74	2.9134	119	4.6851	164	6.4568
30	1.1811	75	2.9528	120	4.7245	165	6.4962
31	1.2205	76	2.9922	121	4.7639	166	6.5356
32	1.2599	77	3.0316	122	4.8032	167	6.5749
33	1.2992	78	3.0709	123	4.8426	168	6.6143
34	1.3386	79	3.1103	124	4.8820	169	6.6537
35	1.3780	80	3.1497	125	4.9213	170	6.6930
36	1.4173	81	3.1890	126	4.9607	171	6.7324
37	1.4567	82	3.2284	127	5.0001	172	6.7718
38	1.4961	83	3.2678	128	5.0395	173	6.8111
39	1.5355	84	3.3071	129	5.0788	174	6.8505
40	1.5748	85	3.3465	130	5.1182	175	6.8899
41	1.6142	86	3.3859	131	5.1576	176	6.9293
42	1.6536	87	3.4253	132	5.1969	177	6.9686
43	1.6929	88	3.4646	133	5.2363	178	7.0080
44	1.7323	89	3.5040	134	5.2757	179	7.0474
45	1.7717	90	3.5434	135	5.3151	180	7.0867

Equivalents of Millimetres in Inches.

(Continued).

Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
181	7.1261	226	8.8978	271	10.6695	316	12.4412
182	7.1655	227	8.9372	272	10.7089	317	12.4805
183	7.2049	228	8.9765	273	10.7482	318	12.5199
184	7.2442	229	9.0159	274	10.7876	319	12.5593
185	7.2836	230	9.0553	275	10.8270	320	12.5987
186	7.3230	231	9.0947	276	10.8663	321	12.6380
187	7.3623	232	9.1340	277	10.9057	322	12.6774
188	7.4017	233	9.1734	278	10.9451	323	12.7168
189	7.4411	234	9.2128	279	10.9845	324	12.7561
190	7.4805	235	9.2521	280	11.0238	325	12.7955
191	7.5198	236	9.2915	281	11.0632	326	12.8349
192	7.5592	237	9.3309	282	11.1026	327	12.8742
193	7.5986	238	9.3702	283	11.1419	328	12.9136
194	7.6379	239	9.4096	284	11.1813	329	12.9530
195	7.6773	240	9.4490	285	11.2207	330	12.9924
196	7.7167	241	9.4884	286	11.2600	331	13.0317
197	7.7560	242	9.5277	287	11.2994	332	13.0711
198	7.7954	243	9.5671	288	11.3388	333	13.1105
199	7.8348	244	9.6065	289	11.3782	334	13.1498
200	7.8742	245	9.6458	290	11.4175	335	13.1892
201	7.9135	246	9.6852	291	11.4569	336	13.2286
202	7.9529	247	9.7246	292	11.4963	337	13.2680
203	7.9923	248	9.7640	293	11.5356	338	13.3073
204	8.0316	249	9.8033	294	11.5750	339	13.3467
205	8.0710	250	9.8427	295	11.6144	340	13.3861
206	8.1104	251	9.8821	296	11.6538	341	13.4254
207	8.1498	252	9.9214	297	11.6931	342	13.4648
208	8.1891	253	9.9608	298	11.7325	343	13.5042
209	8.2285	254	10.0002	299	11.7719	344	13.5436
210	8.2679	255	10.0396	300	11.8112	345	13.5829
211	8.3072	256	10.0789	301	11.8506	346	13.6223
212	8.3466	257	10.1183	302	11.8900	347	13.6617
213	8.3860	258	10.1577	303	11.9293	348	13.7010
214	8.4253	259	10.1970	304	11.9687	349	13.7404
215	8.4647	260	10.2364	305	12.0081	350	13.7798
216	8.5041	261	10.2758	306	12.0475	351	13.8191
217	8.5435	262	10.3151	307	12.0868	352	13.8585
218	8.5828	263	10.3545	308	12.1262	353	13.8979
219	8.6222	264	10.3939	309	12.1656	354	13.9373
220	8.6616	265	10.4333	310	12.2049	355	13.9766
221	8.7009	266	10.4726	311	12.2443	356	14.0160
222	8.7403	267	10.5120	312	12.2837	357	14.0554
223	8.7797	268	10.5514	313	12.3231	358	14.0947
224	8.8191	269	10.5907	314	12.3624	359	14.1341
225	8.8584	270	10.6301	315	12.4018	360	14.1735

Equivalents of Millimetres in Inches.

(*Continued*).

Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
361	14.2129	406	15.9845	451	17.7562	496	19.5279
362	14.2522	407	16.0239	452	17.7956	497	19.5673
363	14.2916	408	16.0633	453	17.8350	498	19.6067
364	14.3310	409	16.1027	454	17.8743	499	19.6460
365	14.3703	410	16.1420	455	17.9137	500	19.6854
366	14.4097	411	16.1814	456	17.9531	501	19.7248
367	14.4491	412	16 2208	457	17.9925	502	19.7641
368	14.4885	413	16.2601	458	18.0318	503	19.8035
369	14.5278	414	16.2995	459	18.0712	504	19.8429
370	14.5672	415	16.3389	460	18.1106	505	19.8822
371	14.6066	416	16.3782	461	18.1499	506	19.9216
372	14.6459	417	16.4176	462	18.1893	507	19.9610
373	14.6853	418	16.4570	463	18.2287	508	20.0004
374	14.7247	419	16.4964	464	18.2680	509	20.0397
375	14.7640	420	16.5357	465	18.3074	510	20.0791
376	14.8034	421	16.5751	466	18.3468	511	20.1185
377	14.8428	422	16.6145	467	18.3862	512	20.1578
378	14.8822	423	16.6538	468	18.4255	513	20.1972
379	14.9215	424	16.6932	469	18.4649	514	20.2366
380	14.9609	425	16.7326	470	18.5043	515	20.2760
381	15.0003	426	16.7720	471	18.5436	516	20.3153
382	15.0396	427	16.8113	472	18.5830	517	20.3547
383	15.0790	428	16.8507	473	18.6224	518	20.3941
384	15.1184	429	16.8901	474	18.6618	519	20.4334
385	15.1578	430	16.9294	475	18.7011	520	20.4728
386	15.1971	431	16.9688	476	18.7405	521	20.5122
387	15.2365	432	17.0082	477	18.7799	522	20.5516
388	15.2759	433	17.0476	478	18.8192	523	20.5909
389	15.3152	434	17.0869	479	18.8586	524	20.6303
390	15.3546	435	17.1263	480	18.8980	525	20.6697
391	15.3940	436	17.1657	481	18.9373	526	20.7090
392	15.4333	437	17.2050	482	18.9767	527	20.7484
393	15.4727	438	17.2444	483	19.0161	528	20.7878
394	15.5121	439	17.2838	484	19.0555	529	20.8271
395	15.5515	440	17.3231	485	19.0948	530	20.8665
396	15.5908	441	17.3625	486	19.1342	531	20.9059
397	15.6302	442	17.4019	487	19.1736	532	20.9453
398	15.6696	443	17.4413	488	19.2129	533	20.9846
399	15.7089	444	17.4806	489	19.2523	534	21.0240
400	15.7483	445	17.5200	490	19.2917	535	21.0634
401	15.7877	446	17.5594	491	19.3311	536	21.1027
402	15.8271	447	17.5987	492	19.3704	537	21.1421
403	15.8664	448	17.6381	493	19.4098	538	21.1815
404	15.9058	449	17.6775	494	19.4492	539	21.2209
405	15.9452	450	17.7169	495	19.4885	540	21.2602

Equivalents of Millimetres in Inches.

(*Continued*).

Mm.	Inches.	Mm	Inches.	Mm.	Inches.	Mm.	Inches.
541	21.2996	586	23.0713	631	24.8430	676	26 6147
542	21.3390	587	23.1107	632	24.8823	677	26.6540
543	21.3783	588	23.1500	633	24.9217	678	26.6934
544	21.4177	589	23.1894	634	24.9611	679	26.7328
545	21.4571	590	23.2288	635	25.0005	680	26.7721
546	21.4965	591	23.2681	636	25.0398	681	26.8115
547	21.5358	592	23.3075	637	25.0792	682	26.8509
548	21.5752	593	23.3469	638	25.1186	683	26.8902
549	21.6146	594	23.3862	639	25.1579	684	26.9296
550	21.6539	595	23.4256	640	25.1973	685	26.9690
551	21.6933	596	23.4650	641	25.2367	686	27.0084
552	21.7327	597	23.5044	642	25.2760	687	27.0477
553	21.7720	598	23.5437	643	25.3154	688	27.0871
554	21.8114	599	23.5831	644	25.3548	689	27.1265
555	21.8508	600	23.6225	645	25.3942	690	27.1658
556	21.8902	601	23.6618	646	25.4335	691	27.2052
557	21.9295	602	23.7012	647	25.4729	692	27.2446
558	21.9689	603	23.7406	648	25.5123	693	27.2840
559	22.0083	604	23.7800	649	25.5516	694	27.3233
560	22.0476	605	23.8193	650	25.5910	695	27.3627
561	22.0870	606	23.8587	651	25.6304	696	27.4021
562	22.1264	607	23.8981	652	25.6698	697	27.4414
563	22.1658	608	23.9374	653	25.7091	698	27.4808
564	22.2051	609	23.9768	654	25.7485	699	27.5202
565	22.2445	610	24.0162	655	25.7879	700	27.5596
566	22.2839	611	24.0556	656	25.8272	701	27.5989
567	22.3232	612	24.0949	657	25.8666	702	27.6383
568	22.3626	613	24.1343	658	25.9060	703	27.6777
569	22.4020	614	24.1737	659	25.9454	704	27.7170
570	22.4414	615	24.2130	660	25.9847	705	27.7564
571	22.4807	616	24.2524	661	26.0241	706	27.7958
572	22.5201	617	24.2918	662	26.0635	707	27.8351
573	22.5595	618	24.3311	663	26.1028	708	27.8745
574	22.5988	619	24.3705	664	26.1422	709	27.9139
575	22.6382	620	24.4099	665	26.1816	710	27.9533
576	22.6776	621	24.4493	666	26.2209	711	27.9926
577	22.7169	622	24.4886	667	26.2603	712	28.0320
573	22.7563	623	24.5280	668	26.2997	713	28.0714
579	22.7957	624	24.5674	669	26.3391	714	28.1107
580	22.8351	625	24.6067	670	26.3784	715	28.1501
581	22.8744	626	24.6461	671	26.4178	716	28.1895
582	22.9138	627	24.6855	672	26.4572	717	28.2289
583	22.9532	628	24.7249	673	26.4965	718	28.2682
584	22.9925	629	24.7642	674	26.5359	719	28.3076
585	23.0319	630	24.8036	675	26.5753	720	28.3470

Equivalents of Millimetres in Inches.

(Continued).

Mm.	Inches	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
721	28.3863	766	30.1580	811	31.9297	856	33.7014
722	28.4257	767	30.1974	812	31.9691	857	33.7408
723	28.4651	768	30.2368	813	32.0085	858	33.7801
724	28.5045	769	30.2761	814	32.0478	859	33.8195
725	28.5438	770	30.3155	815	32.0872	860	33.8589
726	28.5832	771	30.3549	816	32.1266	861	33.8983
727	28.6226	772	30.3942	817	32.1659	862	33.9376
728	28.6619	773	30.4336	818	32.2053	863	33.9770
729	28.7013	774	30.4730	819	32.2447	864	34.0164
730	28.7407	775	30.5124	820	32.2840	865	34.0557
731	28.7800	776	30.5517	821	32.3234	866	34.0951
732	28.8194	777	30.5911	822	32.3628	867	34.1345
733	28.8588	778	30.6305	823	32.4022	868	34.1738
734	28.8982	779	30.6698	824	32.4415	869	34.2132
735	28.9375	780	30.7092	825	32.4809	870	34.2526
736	28.9769	781	30.7486	826	32.5203	871	34.2920
737	29.0163	782	30.7880	827	32.5596	872	34.3313
738	29.0556	783	30.8273	828	32.5990	873	34.3707
739	29.0950	784	30.8667	829	32.6384	874	34.4101
740	29.1344	785	30.9061	830	32.6778	875	34.4494
741	29.1738	786	30.9454	831	32.7171	876	34.4888
742	29.2131	787	30.9848	832	32.7565	877	34.5282
743	29.2525	788	31.0242	833	32.7959	878	34.5676
744	29.2919	789	31.0636	834	32.8352	879	34.6069
745	29.3312	790	31.1029	835	32.8746	880	34.6463
746	29.3706	791	31.1423	836	32.9140	881	34.6857
747	29.4100	792	31.1817	837	32.9534	882	34.7250
748	29.4494	793	31.2210	838	32.9927	883	34.7644
749	29.4887	794	31.2604	839	33.0321	884	34.8038
750	29.5281	795	31.2998	840	33.0715	885	34.8431
751	29.5675	796	31.3391	841	33.1108	886	34.8825
752	29.6068	797	31.3785	842	33.1502	887	34.9219
753	29.6462	798	31.4179	843	33.1896	888	34.9613
754	29.6856	799	31.4573	844	33.2289	889	35.0006
755	29.7249	800	31.4966	845	33.2683	890	35.0400
756	29.7643	801	31.5360	846	33.3077	891	35.0794
757	29.8037	802	31.5754	847	33.3471	892	35.1187
758	29.8431	803	31.6147	848	33.3864	893	35.1581
759	29.8824	804	31.6541	849	33.4258	894	35.1975
760	29.9218	805	31.6935	850	33.4652	895	35.2369
761	29.9612	806	31.7329	851	33.5045	896	35.2762
762	30.0005	807	31.7722	852	33.5439	897	35.3156
763	30.0399	808	31 8116	853	33.5833	898	35.3550
764	30.0793	809	31.8510	854	33.6227	899	35.3943
765	30.1187	810	31.8903	855	33.6620	900	35.4337

Equivalents of Millimetres in Inches.
(*Concluded*).

Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
901	35.4731	926	36.4574	951	37.4416	976	38.4259
902	35.5125	927	36.4967	952	37.4810	977	38.4653
903	35.5518	928	36.5361	953	37.5204	978	38.5046
904	35.5912	929	36.5755	954	37.5597	979	38.5440
905	35.6306	930	36.6148	955	37.5991	980	38.5834
906	35.6699	931	36.6542	956	37.6385	981	38.6227
907	35.7093	932	36.6936	957	37.6778	982	38.6621
908	35.7487	933	36.7329	958	37.7172	983	38.7015
909	35.7880	934	36.7723	959	37.7566	984	38.7409
910	35.8274	935	36.8117	960	37.7960	985	38.7802
911	35.8668	936	36.8511	961	37.8353	986	38.8196
912	35.9062	937	36.8904	962	37.8747	987	38.8590
913	35.9455	938	36.9298	963	37.9141	988	38.8983
914	35.9849	939	36.9692	964	37.9534	989	38.9377
915	36.0243	940	37.0085	965	37.9928	990	38.9771
916	36.0636	941	37.0479	966	38.0322	991	39.0165
917	36.1030	942	37.0873	967	38.0716	992	39.0558
918	36.1424	943	37.1267	968	38.1109	993	39.0952
919	36.1818	944	37.1660	969	38.1503	994	39.1346
920	36.2211	945	37.2054	970	38.1897	995	39.1739
921	36.2605	946	37.2448	971	38.2290	996	39.2133
922	36.2999	947	37.2841	972	38.2684	997	39.2527
923	36.3392	948	37.3235	973	38.3078	998	39.2920
924	36.3786	949	37.3629	974	38.3471	999	39.3314
925	36.4180	950	37.4023	975	38.3865	1000	39.3708

TABLE No. 39.

Equivalents of Inches and Fractions of an Inch in Millimetres.

Millimetres = Inches × 25.39954.

Inch.	Mm.	Inch.	Mm.	Inch.	Mm.	Inch.	Mm.
1/64	.3969	17/64	6.7468	33/64	13.0966	49/64	19.4465
1/32	.7937	9/32	7.1436	17/32	13.4935	25/32	19.8434
3/64	1.1906	19/64	7.5405	35/64	13.8904	51/64	20.2403
1/16	1.5875	5/16	7.9374	9/16	14.2872	13/16	20.6371
5/64	1.9843	21/64	8.3342	37/64	14.6841	53/64	21.0340
3/32	2.3812	11/32	8.7311	19/32	15.0810	27/32	21.4309
7/64	2.7781	23/64	9.1280	39/64	15.4778	55/64	21.8277
1/8	3.1749	3/8	9.5248	5/8	15.8747	7/8	22.2246
9/64	3.5718	25/64	9.9217	41/64	16.2716	57/64	22.6215
5/32	3.9687	13/32	10.3186	21/32	16.6684	29/32	23.0183
11/64	4.3655	27/64	10.7154	43/64	17.0653	59/64	23.4152
3/16	4.7624	7/16	11.1123	11/16	17.4622	15/16	23.8121
13/64	5.1593	29/64	11.5092	45/64	17.8591	61/64	24.2089
7/32	5.5561	15/32	11.9060	23/32	18.2559	31/32	24.6058
15/64	5.9530	31/64	12.3029	47/64	18.6528	63/64	25.0027
1/4	6.3499	1/2	12.6998	3/4	19.0497	1	25.3995

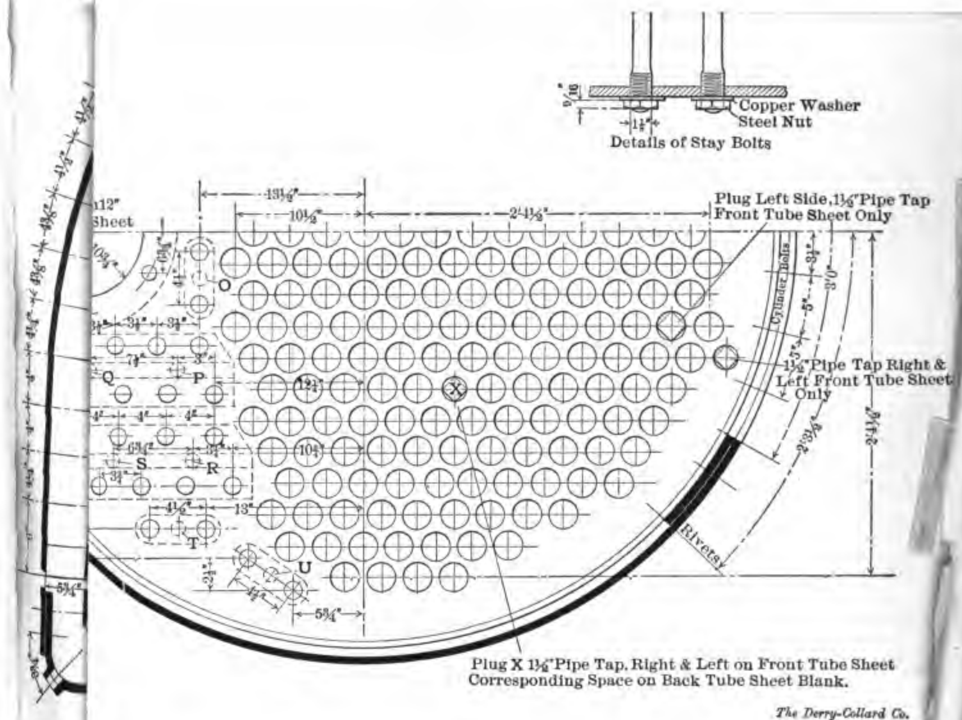
Table No. 40.

Equivalents of Inches and Fractions of an Inch in Milimetres.

Milimetres = Inches × 25.39954.

In.	.0	⅛	¼	⅜	½	⅝	¾	⅞
1	25.400	28.574	31.749	34.924	38.099	41.274	44.449	47.624
2	50.799	53.974	57.149	60.324	63.499	66.674	69.849	73.024
3	76.199	79.374	82.549	85.723	88.898	92.073	95.248	98.423
4	101.60	104.77	107.95	111.12	114.30	117.47	120.65	123.82
5	127.00	130.17	133.35	136.52	139.70	142.87	146.05	149.22
6	152.40	155.57	158.75	161.92	165.10	168.27	171.45	174.62
7	177.80	180.97	184.15	187.32	190.50	193.67	196.85	200.02
8	203.20	206.37	209.55	212.72	215.90	219.07	222.25	225.42
9	228.60	231.77	234.95	238.12	241.30	244.47	247.65	250.82
10	254.00	257.17	260.35	263.52	266.70	269.87	273.05	276.22
11	279.39	282.57	285.74	288.92	292.09	295.27	298.44	301.62
12	304.79	307.97	311.14	314.32	317.49	320.67	323.84	327.02
13	330.19	333.37	336.54	339.72	342.89	346.07	349.24	352.42
14	355.59	358.77	361.94	365.12	368.29	371.47	374.64	377.82
15	380.99	384.17	387.34	390.52	393.69	396.87	400.04	403.22
16	406.39	409.57	412.74	415.92	419.09	422.27	425.44	428.62
17	431.79	434.97	438.14	441.32	444.49	447.67	450.84	454.02
18	457.19	460.37	463.54	466.72	469.89	473.07	476.24	479.42
19	482.59	485.77	488.94	492.12	495.29	498.47	501.64	504.82
20	507.99	511.17	514.34	517.52	520.69	523.87	527.04	530.22
21	533.39	536.57	539.74	542.92	546.09	549.27	552.44	555.61
22	558.79	561.96	565.14	568.31	571.49	574.66	577.84	581.01
23	584.19	587.36	590.54	593.71	596.89	600.06	603.24	606.41
24	609.59	612.76	615.94	619.11	622.29	625.46	628.64	631.81
25	634.99	638.16	641.34	644.51	647.69	650.86	654.04	657.21
26	660.39	663.56	666.74	669.91	673.09	676.26	679.44	682.61
27	685.79	688.96	692.14	695.31	698.49	701.66	704.84	708.01
28	711.19	714.36	717.54	720.71	723.89	727.06	730.24	733.41
29	736.59	739.76	742.94	746.11	749.29	752.46	755.64	758.81
30	761.99	765.16	768.34	771.51	774.69	777.86	781.04	784.21
31	787.39	790.56	793.74	796.91	800.09	803.26	806.44	809.61
32	812.79	815.96	819.14	822.31	825.49	828.66	831.83	835.01
33	838.18	841.36	844.53	847.71	850.88	854.06	857.23	860.41
34	863.58	866.76	869.93	873.11	876.28	879.46	882.63	885.81
35	888.98	892.16	895.33	898.51	901.68	904.86	908.03	911.21
In.	.0	⅛	¼	⅜	½	⅝	¾	⅞

Index.



The Derry-Collard Co.

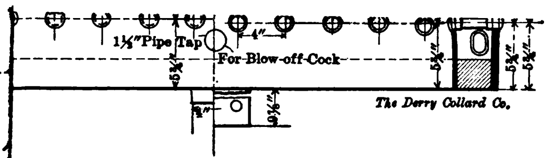
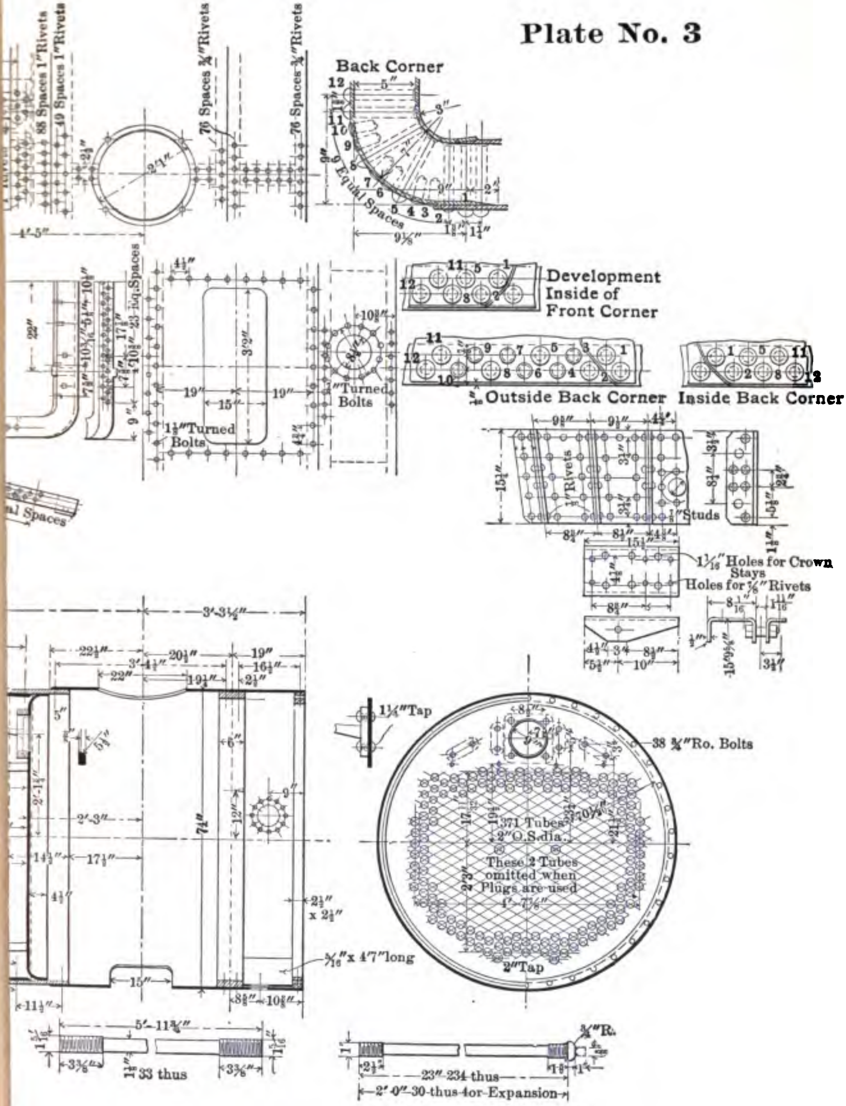


Plate No. 2

Plate No. 3



The Derry Collard Co.

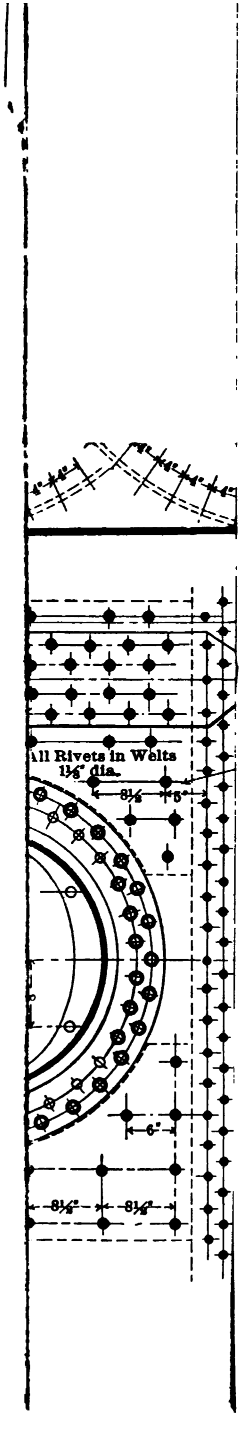
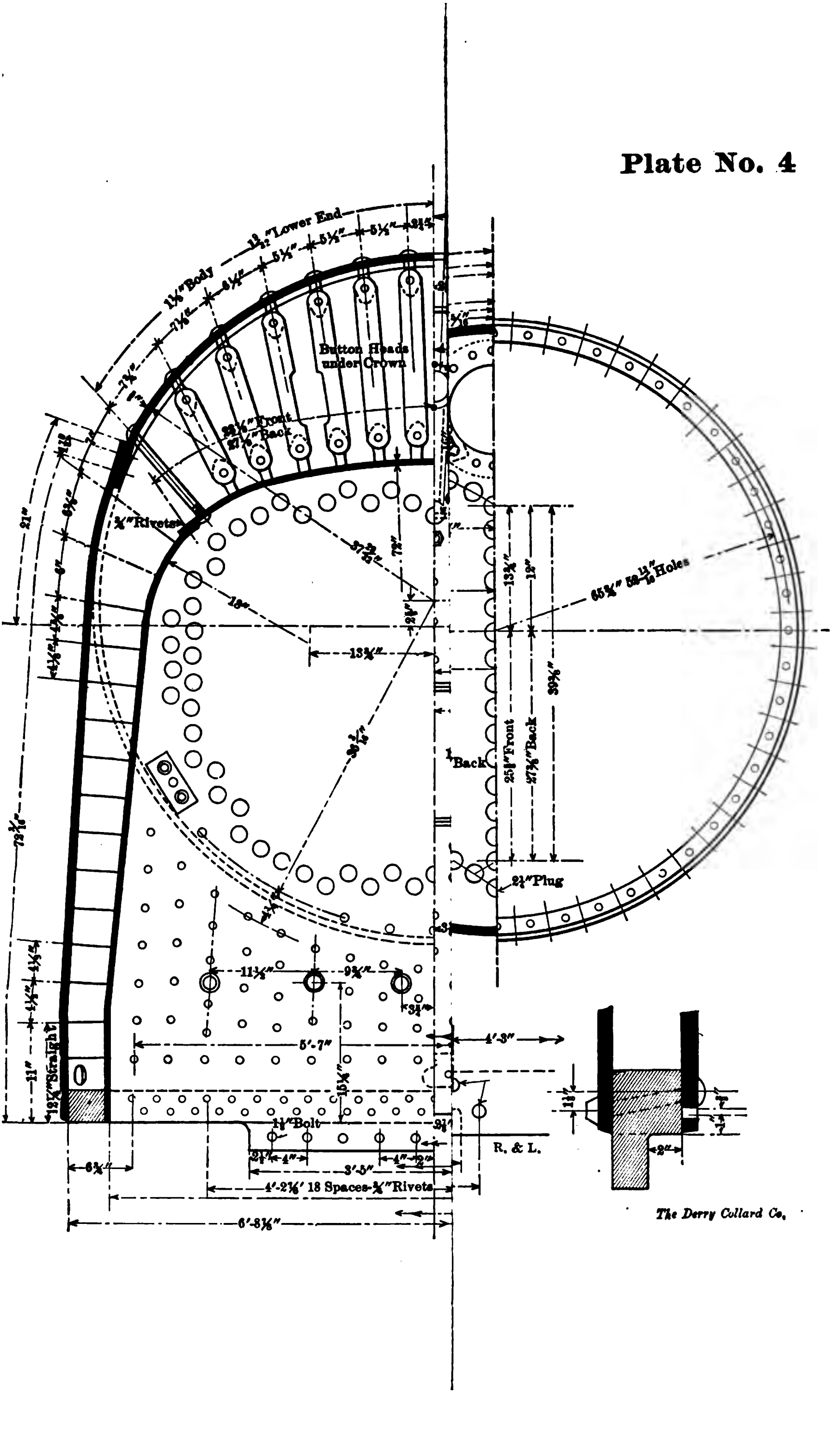
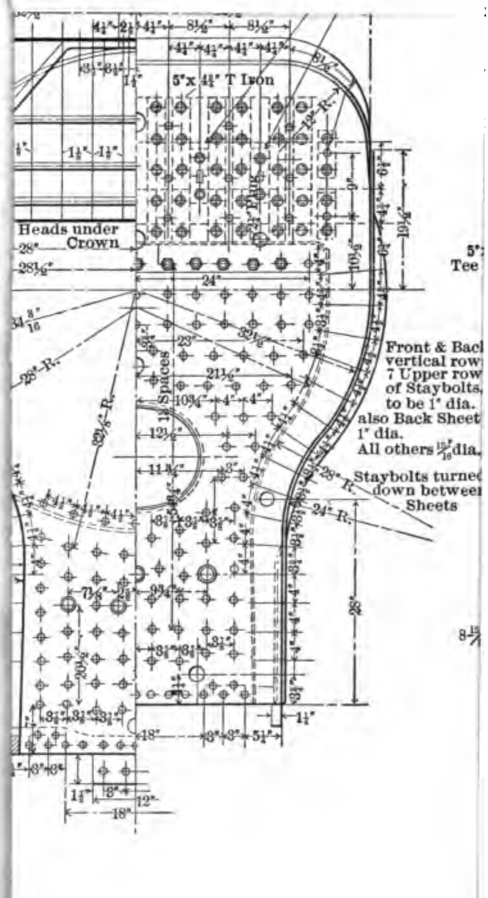

All Rivets in Welts
1⅛" dia.
8½
5"
6"
8½"
8½"

Plate No. 4



The Derry Collard Co.


5"x 4½" T Iron
Heads under Crown
Front & Bac
vertical row
7 Upper row
of Staybolts,
to be 1" dia.
also Back Sheet
1" dia.
All others 15/16" dia.
Staybolts turned
down between
Sheets
Tee
24" R.
28" R.
12" R.
1½"
18"
12"
24"
28"